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APPENDIX A:

A COPY OF A MASTERS THESIS ENTITLED

"MOBILE COMPUTER NETWORK ARCHITECTURE"

MOBILE COMPUTER NETWORK ARCHITECTURE

by

Robert C. Meier

A thesis submitted in partial fulfillment
of the requirements for the Master of
Science degree in Computer Science
in the Graduate College of
The University of Iowa

August 1993

Thesis supervisor: Professor Donald Epley

TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

Figure		Page

CHAPTER I

INTRODUCTION

Mobile Computer Network Architecture (MCNA) is a computer network architecture designed to connect mobile interactive radio-equipped computers to an infrastructure of stationary computer devices. The network architecture is based on protocol layering principles developed by the International Standards Organization (ISO) for Open Systems Interconnection (OSI). The ISO/OSI model specifies seven distinct communications layers. Each layer provides a distinct service and isolates other layers from changes in the computer network. MCNA implements the first four protocol layers - 1) the physical layer, 2) the data link layer, 3) the network layer and 4) the transport layer. The physical layer includes short-range spread spectrum radio links to facilitate terminal mobility. Multiple overlapping radio coverage areas are used to provide a multi-hop data path from intelligent mobile radio-equipped computers to a fixed network of computers and to other radio-equipped computers. Multi-hop radio links, overlapping radio coverage areas, and mobile network nodes present unique network design issues which are primarily addressed by the

data link layer and the network layer. This thesis defines network requirements and design issues which influenced the development of MCNA, and then presents data link and network layer solutions and transport layer requirements in the context of a specific hardware solution and a working functional model.

Summary of Contributions

The radio networking concepts presented in this thesis include extensions and adaptations of earlier work, and include original work by the author which is listed in patent applications filed by Norand Corporation of Cedar Rapids, Iowa. The problems and design issues related to packet radio networking are well documented in several of the listed references. Nielson and Tobagi provide the best summary of packet radio design issues in [1]. The data link layer presented in this thesis includes a channel reservation technique which has been used in earlier **collision avoidance** protocols designed for wired links. The network layer organizes nodes into a spanning tree. Spanning trees are commonly used for network layer routing; however, the approach used in MCNA was actually inspired by the IEEE 802.1 standard for transparent bridging. Backes provides an excellent overview of the 802.1 bridging standard in [9]. It should be noted that MCNA and transparent bridging are considerably different. MCNA

defines a layered protocol stack for a packet switched network. Transparent bridging defines a method for forwarding data link frames across local area subnets and is not a part of any protocol layer. The transport layer used in MCNA is an extension of the IEEE 802.2 logical link control standard described in [10].

Organization of Thesis

Chapter II contains an overview of MCNA and presents design issues which affected the development of the MCNA protocol stack.

Chapter III contains a detailed description of the MCNA data link layer which encompasses channel access and logical link control.

Chapter IV contains a detailed description of the MCNA network layer.

Chapter V contains a brief description of the functions and services provided by the MCNA transport layer. A detailed specification of the transport layer can be found in [10].

Chapter VI summarizes advantages of the MCNA approach and discusses possible extensions to MCNA.

CHAPTER II

NETWORK OVERVIEW

Logical nodes

A logical **node** in the MCNA network is an addressable protocol entity. The network contains two logical node types: 1) **terminal** nodes and 2) **router** nodes. Figure 1 shows the protocol stacks for both node types. The arrows represent the flow of data between layers in the stacks.

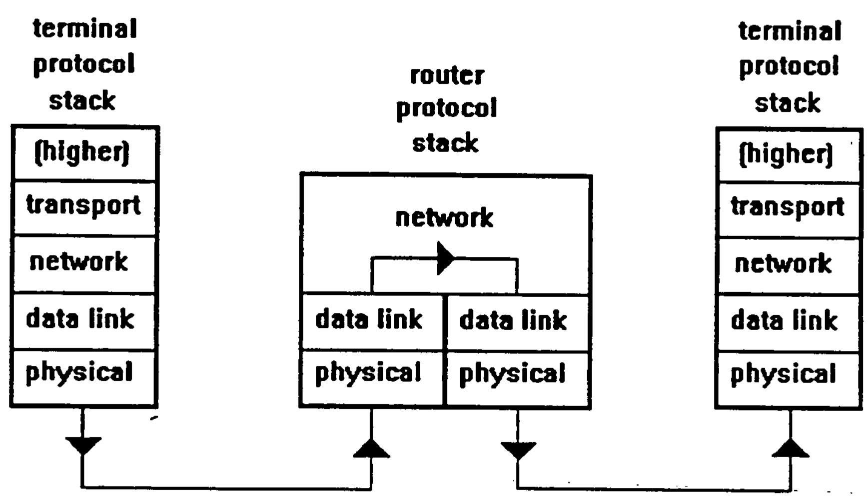

Figure 1. Terminal and Router Protocol Stacks

Terminal nodes are end points in the network; router nodes are used to forward data packets at the network layer. Any logical terminal can communicate with any other logical terminal at the network layer. The network is designed to support up to 1000 logical terminals which correspond to hardware devices such as radio-equipped computers, host computers, printers, etc.

Physical devices

A typical MCNA network might consist of the following hardware device types:

Base station - A stationary radio-equipped computer which is used to extend the range of a controller node. Base-station-to-controller links or base-station-to-base-station links can be wired or radio. Base stations contain a single router node.

Mobile Radio-equipped Computer (MRC) - A radio-equipped mobile computer which contains one or more terminal nodes. MRCs are often battery powered and go into a **sleeping** state whenever possible to conserve power. An MRC does not receive network data while it is sleeping. The MCNA network provides several features to accommodate sleeping terminal nodes. MRCs communicate with base stations at the data link layer.

Controller - A **gateway** device which connects peripheral devices to the network. A controller contains one router

node and one or more terminal nodes. Each controller-based terminal node corresponds to an attached peripheral device. A typical MCNA network has one or more controller devices.

Peripheral Device - Any device which does not directly support the MCNA protocol stack, such as a printer or host computer. A peripheral device must be connected to a controller device and is represented by a terminal protocol stack in the controller.

Host Computer (or host) - A computer which communicates with associated MRCs in an MCNA network. A host computer can be viewed as a peripheral device.

<u>Communications links</u>

A communication **link** is used to make a physical layer connection between devices. In an MCNA network, physical layer connections can be made with either wired or radio links. Each link is restricted to a single communications **channel**, where a channel can accommodate only one data transmission at any given time. (In some networks, frequency or time division multiplexing can be used to multiplex multiple communications channels on a single physical link.) The network architecture assumes that <u>both radio and wired links provide a broadcast medium at the data link layer</u>. All unicast and multicast data link frames transmitted on a medium are received by all nodes physically connected to the medium.

Low-power direct-sequenced spread-spectrum radio is used to facilitate mobility for MRCs. The bit rate of the spread-spectrum radio channel is approximately 200 Kbps. Although the coverage area of a single radio transmitter is restricted, the total radio coverage area of an MCNA network must be virtually unlimited by the network design. Multiple base stations are used to extend the radio coverage area. It is a requirement that MRCs can move freely throughout the total coverage area without significant response time and throughput penalties. **Roaming** is the process of moving out of the coverage area of one base station and into the coverage area of a second base station. Link level error rates are relatively high on radio links due to roaming (and the nature of the medium).

Base stations and controllers can be connected on a multi-drop relatively high-speed wired backbone LAN. (Note that if an IEEE 802 medium access LAN standard is used for the backbone LAN, multicast IEEE 802.1 addresses are required to broadcast unicast data link frames at the medium access control sublayer.) Base stations can also be connected on radio links, at the physical layer. A peripheral device can be connected to an MCNA controller by any physical standard which both devices support. As noted above, a peripheral device is represented by a terminal protocol stack in an attached controller; therefore, the

physical connection to a peripheral device is not considered to be an MCNA network link. Differences in MCNA physical layer links are hidden from higher layers by the MCNA data link layer.

Figure 2 shows an example MCNA network. Note that base stations can be wired (i.e. to the backbone LAN) or wireless.

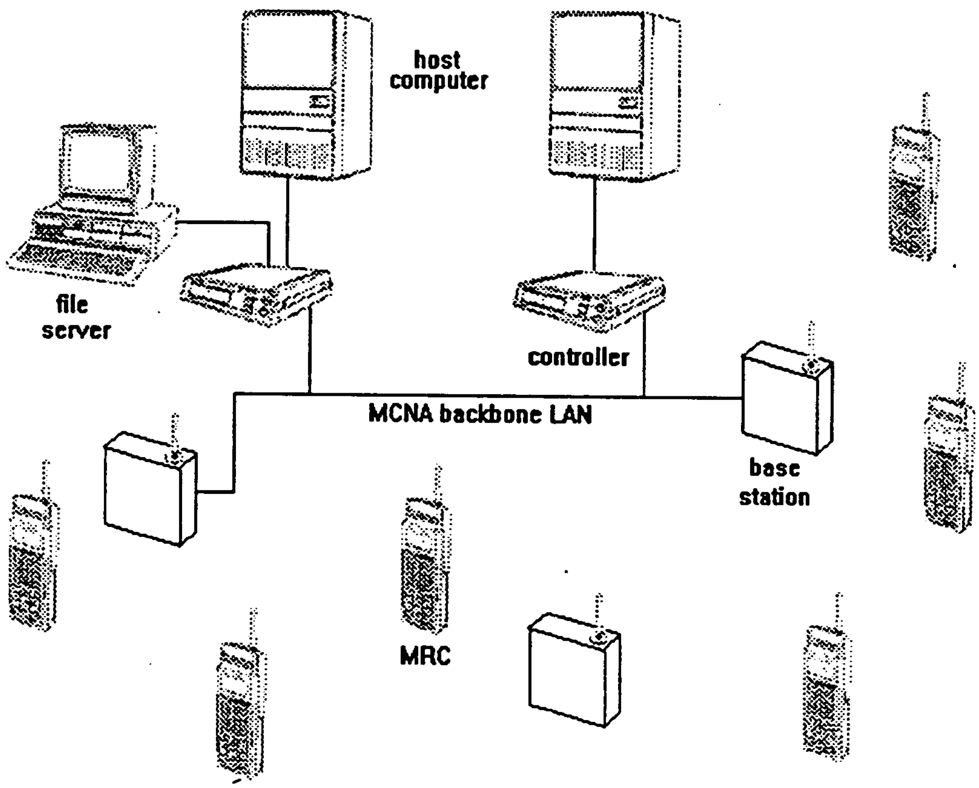

Figure 2. An example MCNA Network

<u>Network addresses</u>

Data link frames contain a hop destination and hop source address in the data link header. Network layer packets contain an end-to-end destination and source address in the network header. Transport headers contain source and destination **service access point** (**SAP**) identifiers. Data link and network addresses are consistent and have the same format.

All devices must have either a unique **long identifier** which is programmed into the device at the factory and/or an **alias** which is typically entered by the user and is well-known. The long address and/or alias binds to a short 16-bit **network address**, obtained from an **address server**. A network address uniquely identifies a logical terminal or router node.

Network addresses consist of 2 parts: a 1) **node type** and a 2) 11-bit **node identifier**. MCNA has terminal and router node types. A node type of all 1's is used to specify all node types. The node identifier is used to uniquely identify a node of the specified type. A node identifier of all 1's is used to specify any node of the associated type. Note that a node type of all 1's and a node identifier of 1's can be used to specify all nodes.

A unicast address is used to identify a single MCNA node. A multicast or broadcast address is used to identify

a group of nodes. The high-order bit is always set ON in a multicast or broadcast address. The high-order bit can be set ON in a unicast address to turn off data link handshaking.

The default network address used when a data link entity is first enabled consists of the multicast node type concatenated with a node identifier of all 1's. For example, the default address for a router node is hexadecimal A7FF. The network layer is responsible for obtaining a network address and assigning it to the data link entity assigned to a physical port.

In addition, to source and destination addresses, each transmitted network packet contains an MCNA **network identifier** (**LAN ID**) in the data link header. The network identifier is used to filter radio traffic from adjacent MCNA networks.

Network design issues

Although MCNA is designed to be a general purpose network architecture, terminal emulation is the predominant application which MCNA is required to support. In an example emulation system, an MRC might look like a data entry terminal to a host computer. In this case, a controller attached to the host computer (directly or indirectly) would contain a logical terminal node which provided a gateway to the host. The application on top of

the logical terminal protocol stack might emulate a terminal controller device. In addition to terminal emulation, the network must facilitate mail messaging, file transfers, and client-server applications.

Due to the nature of the supported applications, data traffic in an MCNA network is normally bursty and light, but can be heavy at times. Fast on-line response times for terminal emulation are essential, but the network can not go into an overloaded state when traffic occasionally gets heavy.

MCNA is a fully-interconnected network at the transport layer. For example, in figure 2, any of the MRCs in the network can log onto either host, can send mail messages to each other, or request records from the file server.

Most network architectures fall into one of two categories: 1) packet-switching, or 2) circuit-switching. In a packet-switched network, each data packet associated with a transport layer connection can be routed along a different path. Packets can be lost and arrive out of order. In a circuit-switched network, a fixed path, called a virtual circuit, is defined when a transport layer connection is established. Packets always arrive in order and are rarely lost. In an MCNA network, radio links (and data packets) can be lost frequently if an MRC roams during a transport layer connection. The frequent loss of physical

links prohibits the use of pure circuit-switching at the network layer.

In a packet-switched (or circuit-switched) network, nodes periodically exchange or distribute routing tables so that each node can learn the path to other nodes in the network. Routing table entries typically contain the **cost** to other nodes in the network and allow a node to select the best first **hop** to use to send data to another node. Unscheduled routing table exchanges can be triggered when the cost to a node suddenly changes significantly, possibly due to a node or link failure. The overhead associated with routing table exchanges can be significant, even when physical links are relatively stable. Several factors preclude the use of routing table exchanges in an MCNA network: 1) radio links are transient, 2) the primary application requires consistent fast response times, and 3) the bandwidth on the radio channel is limited. Frequent table exchanges, triggered by the loss of radio links, would be required to support fast response times for roaming MRCs. It is easy to envision a network saturated by routing table exchanges.

In an MCNA network, logical nodes are organized into a **spanning tree** with a router node at the root of the tree. Other router nodes serve as interior nodes in the tree and terminal nodes are leaves in the tree. With the exception of

the root node, each (child) node is connected by a single logical link to a parent node. Parent router nodes may have multiple children. Like a sink tree, nodes closer to the root node of the spanning tree are said to be **downstream** from nodes which are further away. Conversely, all nodes are **upstream** from the root. Network layer packets are routed along branches of the spanning tree. Router nodes use a technique called **backward learning**, to "learn" the path to upstream nodes (i.e. nodes in the subtree rooted at the router). The explicit exchange of routing tables is not required.

Responsiveness and guaranteed throughput, especially under heavy loads, are often conflicting goals in network design. Maximum throughput under heavy loads can be guaranteed by token-passing or polling schemes. Nodes gain access to a communications channel only after receiving a token or poll (i.e. from a master node). Responsiveness is degraded since a node must wait for a token or poll in order to communicate. On lightly loaded networks, the best response times (i.e. for on-line applications) can be obtained by using a technique called **multiple access**. In a multiple access system, nodes are allowed to access the channel asynchronously, without waiting for a poll or token. However, throughput under heavy loads can be degraded due to **contention** - multiple concurrent access to a communications

channel resulting in **collisions**. In a **carrier-sense/multiple access** (**CSMA**) or **listen-before-talk** (**LBT**) multiple access system, collisions are reduced because nodes "listen" to the channel, to determine if it is busy, before accessing the channel. Hybrid channel access techniques exist, which allow multiple access to the channel under light loads, but which migrate to a polling scheme as traffic increases. Such techniques usually require coordination from a master node.

As mentioned earlier, MCNA must provide fast response times for bursty traffic from up to 1000 nodes. The time required for polling or passing a token to idle nodes prohibits the use of a polling or token-passing scheme. The coordination required for any sort of hybrid scheme is complex, since a network can contain multiple overlapping coverage areas. No single "master" node can be heard throughout the radio network. Polling, token-passing, or hybrid schemes are even more difficult to implement if the network contains sleeping nodes. MCNA uses a multiple access technique on both wired and radio communications channels. The technique is called **Listen-Before-Talk Channel Reservation with Busy Pulse** (**LBTCR/BP**), and is described in detail below.

Packet radio networks present unique channel access design issues, which are not present in wired networks. The

existence of multiple overlapping radio coverage areas can be both an advantage and disadvantage. The total data rate on the radio network can actually exceed the bandwidth of the radio channel due to a phenomenon called **spatial reuse**. Two pairs of MRCs can communicate concurrently, if the radio coverage area of the first pair is disjoint from the coverage area of the second pair. Concurrent communications sessions are possible even when coverage areas are not disjoint due to the **capture effect**. The capture effect allows a radio receiver to correctly interpret the signal from a strong transmitter in the presence of signals from weaker transmitters.

A CSMA or LBT scheme is more complicated in a multi-hop radio network due to the presence of **hidden nodes**. A node is said to be "hidden" from a transmitter if it is not in the coverage area of the transmitter, but is within the coverage area of the intended receiver. Figure 3 shows one example of hidden nodes. The circles represent the radio coverage areas of each of the nodes - A, B, C, and D. Consider the following scenario. Assume A is transmitting to B. C now wants to begin a conversation with D. Since C can not hear A, C assumes the channel is idle and begins transmitting to D. Since B is in the coverage area of both A and C, it will lose the transmission from A.

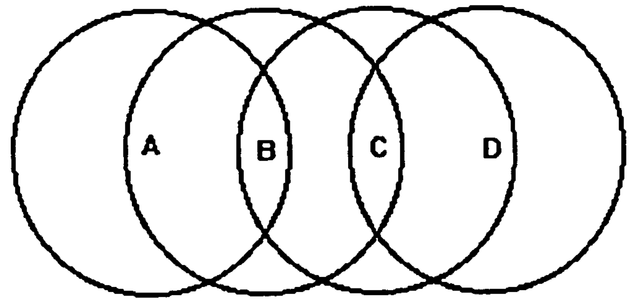

Figure 3. Coverage Areas with Hidden Nodes

The design of a packet radio network is also complicated by the existence of transient and unidirectional radio links. Links can be transient because the range and quality of a radio link can vary over time. A link can be unidirectional because transmitter strength and receiver sensitivity can vary from node to node.

CHAPTER III

DATA LINK LAYER

The MCNA Data Link layer controls access to the channel and is responsible for providing reliable transmission between any two devices in the network (i.e. MRC-to-base-station), on both wired and radio links. MCNA's data link layer has a **Medium Access Control (MAC)** component and a **Data Link Control (DLC)** component. The MAC and DLC components of the MCNA data link layer are not strictly layered and can not be presented independently. This paper focuses on the data link layer used on radio links, however the radio DLC component is also appropriate for wired links with significant error rates (i.e. due to access collisions). The radio MAC can be used on wired LAN links if an underlying MAC service is not provided by the LAN standard (i.e. IEEE 802.3).

Functional requirements

The data link layer: 1) accepts frames from the network layer and passes frames to the physical layer for transmission; 2) appends data link layer framing bytes and CCITT-16 **frame check sequence (FCS)** bytes to transmitted

multicast and unicast frames; 3) removes data link layer framing bytes and FCS bytes from received frames; 4) verifies the FCS bytes in received frames; 5) filters out frames which do not belong to the MCNA network of the local device; 6) filters out packets which are not directed to the local device; 7) forwards packets to the network layer which are addressed to the local device, or are broadcast or multicast to the local device; 8) regulates access to the communications channel on wired LAN links and spread spectrum radio links; 9) recovers lost unicast frames; 10) maintains and provides diagnostic statistics; and 11) transparently fragments and reassembles network layer packets, which exceed the maximum data link frame size. A group of frames which is associated with a single network layer packet is called a **bracket**.

Data Link Control

Data Link Control services

The DLC component provides "acknowledged connectionless" services to the MCNA network layer. A data link connection is not required to transmit a network layer packet; however, each packet is acknowledged at the data link layer and errors are reported to the network layer. The network layer uses a DL_UNITDATA.request primitive to transmit a unicast packet to a child or parent node or to

transmit a multicast packet to a group of nodes. The network layer receives a DL_UNITDATA.indication when a packet is received. The network layer can enable and disable the data link layer with DL_START and DL_STOP, respectively.

Data Link Control frame definitions

All DLC frames contain a destination address, a source address, a data link control byte, and a channel reservation field in the DLC header. Bits in the DLC control byte are used to specify the frame type. DLC frames are one of two types: 1) request, or 2) response, depending on the state of the REQ/RSP control bit.

Table 1 briefly describes each of the request and response frame types. Table 2 briefly describes several control byte fields.

The source address, in the DLC header, is the network address of the local node. The destination address is passed to the DLC by the network layer. The destination (or source) can be a broadcast, multicast, or unicast address. If the destination (or source) is a multicast address, then the DLC transmits the network layer packet as a single multicast EOD frame.

Table 1. DLC Frame Types

a. Request Frame Types

DATA	request frame used to send data in a bracket of frames containing network layer data
EOD	end-of-data request frame used to send the last data frame in a bracket of frames containing network layer data. Note that a bracket of frames may contain a single multicast EOD frame.
RFP	request-for-poll request frame used to request polling from the destination node. An RFP is used to initiate the transmission of a unicast bracket of frames.
ENQ	inquiry frame used to determine the frame sequence state of the destination and used to abort an active transmission.

b. Response Frame Types

POLL	response frame used to solicit the next DATA or EOD frame, in a bracket, from the destination.
WAIT	response frame which is used to notify the destination that the local node is busy.
CLEAR	response frame used to signal the end of the transmission of a unicast bracket of frames.
REJECT	response frame used to indicate that a request frame is invalid or that the frame sequence state is undefined.

Table 2. DLC Control Fields

REQ/RSP	The REQ/RSP bit is set OFF in request frames and is set ON in response frames.
SEQ	The SEQ bit is used to sequence DLC frames in a unicast bracket, modulo 2. The SEQ bit is used to detect duplicate frames.
MORE	In data request frames, the MORE bit is used to distinguish between DATA frames and EOD frames. The last frame sent in a bracket of data frames is always an EOD frame.
PRIORITY	The priority bit is set ON in request frames for high priority data transmissions. MCNA provides normal and high priority data pipelines.
LAN ID	The LAN ID bits contain a network identifier. Frames which do not belong to the local network are discarded.

Bracket transmission

In the discussion which follows, "source" is used to denote a node sending request frames and "sink" is used to denote a node sending response frames. On radio links (and, optionally, on wired links), the DLC fragments a network layer unicast packet into short fixed length frames before the packet is sent. The fragments are reassembled by the sink and are posted to the sink's network layer if, and only if, all frames in the packet are received. As noted above, a group of frames which is associated with a single network layer packet is called a bracket. Fragmentation at the data link layer allows the DLC entity to use a frame size which

is suitable for the link error rate without impacting packet sizes at the network layer.

Figure 4 illustrates an example data link unicast conversation between two nodes - A and B. A conversation is initiated when the network layer in node A posts a DL_UNITDATA.request to the DLC layer in A. After the channel is accessed by the data link MAC component, DLC A sends an RFP frame to DLC B. DLC B responds with a POLL frame to solicit DATA frames from DLC A. The last data fragment in the bracket is sent, by DLC A, in an EOD frame. DLC B responds with a CLEAR frame which ends the conversation.

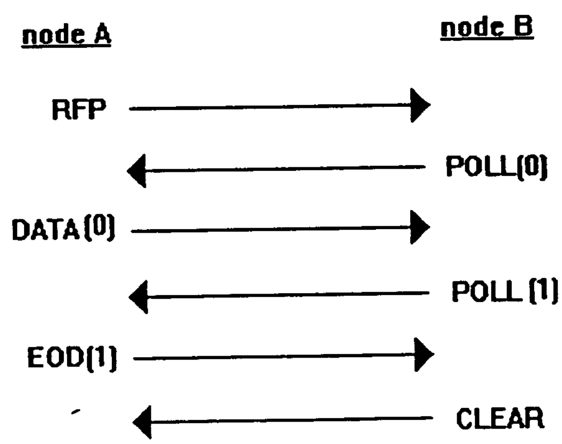

Figure 4. Example DLC Bracket Transmission

Figure 5 shows a timing graph for the example bracket transmission in figure 4.

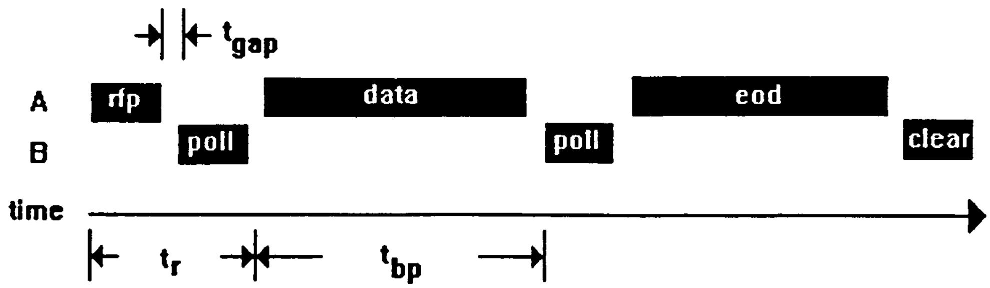

Figure 5. DLC Bracket Transmission Timing Graph

The example transmission illustrated in figures 4 and 5 assumes that no errors occurred. A data link error can occur if a frame is lost or corrupted. A frame check sequence field is appended to the end of all data link frames. The FCS field is used to perform a complimentary transmitter/receiver cyclic redundancy check on each frame to determine if the frame was corrupted. Corrupted frames are ignored by the data link layer and are viewed as lost. The DLC component of the data link layer is responsible for retransmitting lost unicast fragments. The sink is primarily responsible for error recovery during a unicast conversation. If a DATA or EOD frame fragment is lost, the sink times out and resends a POLL frame to solicit

retransmission of the fragment. A 1-bit sequence number is used to determine whether a POLL is for the previous (i.e. lost) fragment or the next fragment. The sequence number is reset to 0 at the start of a conversation. The source is responsible for recovery from lost RFP frames. (It should be noted that an ambiguous situation can occur when a source sends an RFP frame and misses the first POLL frame from the sink. The source can not distinguish the missed POLL from a lost RFP and, as a result, both the source and sink actively attempt to recover.) If a CLEAR frame is missed in a unicast sequence, the source can send an ENQ frame to determine the status of the conversation. If the CLEAR was lost, the sink responds to an ENQ by resending the CLEAR. A REJECT is sent to indicate that the sink exceeded a MAX_POLL_RETRY count and did not receive the EOD fragment. If a sink does not respond, a radio source can assume that the sink is no longer in range. A sink must cache the appropriate receive state information to determine whether a CLEAR or REJECT should be returned in response to an ENQ.

A source can reset an active conversation, at any time before the EOD frame is sent, by resending the RFP frame. A source can abort an active conversation by sending an ENQ frame.

Frame/packet filtering

When the DLC entity is in an ENABLED/ON state it is continuously listening on its assigned port. The DLC entity receives all data link layer frames. Frames which do not pass an FCS check are invalid and are discarded. Valid data frames are reassembled into a complete packet which is posted to the network layer if: 1) The LAN ID in the DLC header matches the LAN ID of the local node, and 2) The destination address in the DLC header a) is equal to the network address of the local node, or b) is an acceptable multicast or broadcast address.

The high-order multicast bit is set ON in all multicast or broadcast frames. A multicast or broadcast frame is accepted if the node type specifies a group to which the local node belongs and either a) the node identifier is all 1's, or b) the node identifier is equal to the identifier of the local node. A response is never required when the multicast bit is set ON.

Transmit and Receive State Machines

State logic is not required to transmit multicast and broadcast frames. Multicast and broadcast frames can be transmitted in a single segment whenever the channel is available. Received multicast or broadcast frames are simply posted to the network layer if the destination node belongs to the specified multicast or broadcast group.

Unicast bracket transmission is best described in the context of a transmit and receive state machine. A source node uses a **transmit state machine** to send a bracket of unicast frames to a sink node. A sink node use a **receive state machine** to receive a bracket of unicast frames. A node can not be in the transmit state machine and receive state machine at the same time. An active node is in one of three high level states: 1) LISTEN, 2) TRANSMIT, or 3) RECEIVE. A node in the LISTEN state is not in either the transmit or receive state machine. A node in the TRANSMIT state is in the transmit state machine. A node in the RECEIVE state is in the receive state machine. Only one bracket transmission can be in progress per node at any time.

<u>Bracket Transmit State Machine</u>

The transmit state machine specifies source actions which are dependent on the current state and the input to the state machine. Transmit state input is limited to: 1) unicast response frames addressed to the local node, and 2) transmit state timers.

Transmit state descriptions

States in the DLC transmit state machine are described below:

IDLE - The state machine is idle and is waiting for a bracket of frames to transmit.

READY - The state machine has a bracket of frames to transmit and is waiting to acquire the channel.

S_RFP - The state machine has sent an RFP frame and is waiting for a POLL frame.

S_DATA - The state machine has sent a DATA frame and is waiting for a POLL frame.

S_EOD - The state machine has sent an EOD frame and is waiting for a CLEAR frame.

RDY_ENQ - The state machine has lost a CLEAR frame and is waiting to acquire the channel before sending an ENQ frame.

Transmit state timers

The transmit state machine requires three timers: A RSP_TIMEOUT receive timer is started when an RFP or ENQ frame is transmitted. The time-out value is larger than the interframe gap time plus the time required to transmit a POLL or CLEAR frame. If the RSP_TIMEOUT timer expires before an expected response is received, a retry counter is incremented and the RFP or ENQ request frame is retransmitted, if the retry count has not been exceeded.

A POLL_TIMEOUT timer is started whenever a DATA or EOD frame is transmitted following the reception of a POLL frame. The time-out value is larger than the time required

for the maximum number of poll retry attempts. The DLC layer returns an error to the network layer if the timer expires before an expected POLL frame is received. Note that the sink is responsible for recovery when the POLL_TIMEOUT timer is running.

A TX_WAIT timer is started whenever a node is in the transmit state machine and is waiting to access the channel.

The transmit state machine maintains an internal sequence state variable which is equal to the 1-bit sequence value of the next frame to transmit. The sequence variable is reset to 0 at the beginning of a conversation and follows the state of the SEQ bit in received POLL frames. The SEQ bit in POLL frames is the sequence number of the next frame expected. Successive POLL frames with the same sequence number cause a DATA or EOD frame to be retransmitted. A DATA or EOD frame is "accepted" when a POLL or CLEAR frame is received with the next sequence number.

The state machine must maintain a "current pointer" variable which points to the current frame, in a bracket of frames, to be transmitted. The current pointer is advanced if, and only if, a POLL for the next frame in the bracket is received. The transition taken when a POLL frame is received depends on whether the current pointer is pointing to a DATA or EOD frame.

Table 3. DLC Transmit State Transition Table

state	event	action	next state
IDLE	A bracket of frames is passed to the state machine	Reset retry count; execute channel access algorithm	READY
READY	Channel acquired	Increment retry count; send RFP frame; start RSP_TIMEOUT timer	S_RFP
S_RFP	RSP_TIMEOUT timer expires and max. retry count exceeded	Return error	IDLE
	RSP_TIMEOUT timer expires	Execute channel access algorithm	READY
	POLL received	Send current DATA frame; start POLL_TIMEOUT timer	S_DATA
	POLL received	Send current EOD frame; start POLL_TIMEOUT receive timer	S_EOD
	WAIT received	Start TX_WAIT timer	IDLE
	REJECT received	Return error (invalid transition)	IDLE
S_DATA	POLL_TIMEOUT timer expires	Return error	IDLE
	POLL received	Advance current pointer if frame was accepted; send current DATA frame; start POLL_TIMEOUT timer	S_DATA
	POLL received	Advance current pointer if frame was accepted; reset retry count; send current EOD frame; start POLL_TIMEOUT timer	S_EOD
	REJECT received	Return error (invalid transition)	IDLE

Table 3--continued

S_EOD	POLL_TIMEOUT timer expires	Reset retry count; execute channel access algorithm	RDY_ENQ
	POLL received	Retransmit EOD frame; start POLL_TIMEOUT timer	S_EOD
	CLEAR received; EOD frame not accepted	Return error (invalid transition)	IDLE
	REJECT received	Return error (invalid transition)	IDLE
	CLEAR received; EOD frame accepted	Return good	IDLE
RDY_ENQ	Channel acquired	Increment retry count; send ENQ; start RSP_TIMEOUT timer	S_ENQ
S_ENQ	RSP_TIMEOUT timer expires and max. retry count exceeded	Return error	IDLE
	RSP_TIMEOUT timer expires	Execute channel access algorithm	RDY_ENQ
	CLEAR received; EOD frame not accepted	Return error (invalid transition)	IDLE
	REJECT received	Return error (invalid transition)	IDLE
	CLEAR received; EOD frame accepted	Return good	IDLE

Table 3 specifies state transitions for unicast bracket transmissions.

Bracket Receive State Machine

The receive state machine specifies sink actions which are dependent on the current state and the input to the state machine.

Table 4. DLC Receive State Transition Table

state	event	action	next state
IDLE_LISTEN	RFP received	Send POLL; reset retry count; start RSP_TIMEOUT timer	BUSY
	ENQ received; entry for source node is in the SEQ state table	Send CLEAR	IDLE_LISTEN
	ENQ received; no entry for source node in the SEQ state table	Send REJECT	IDLE_LISTEN
	DATA or EOD received	Send REJECT	IDLE_LISTEN
BUSY	RSP_TIMEOUT timer expires; max. retries exceeded	Flush; delete SEQ state table entry	IDLE_LISTEN
	RSP_TIMEOUT timer expires	Increment retry count; execute channel access algorithm; acquire channel; resend POLL; start RSP_TIMEOUT timer	BUSY
	DATA received from active node	Reset retry count; send next POLL; start RSP_TIMEOUT timer	BUSY
	DATA or EOD received from inactive node	Send REJECT	BUSY
	EOD received from active node	Send CLEAR; reassemble and post complete packet; flush	IDLE_LISTEN
	ENQ received from inactive node; entry for source node in SEQ state table	Send CLEAR; flush	BUSY
	ENQ received from inactive node; no entry for source node in SEQ state table	Send REJECT; flush	BUSY

Table 4--continued

	ENQ received from active node	Send REJECT ; flush; delete SEQ state table entry	IDLE_LISTEN
	RFP received from inactive node	Send WAIT	BUSY
	RFP received from active node	Send POLL; reset retry count; start RSP_TIMEOUT timer	BUSY

Receive state input is limited to: 1) unicast request frames addressed to the local node, and 2) receive state timers.

Receive state descriptions

States in the receive state machine are described below:

IDLE_LISTEN - The receiver is not receiving a bracket of frames.

BUSY - The receiver has sent a POLL frame and is waiting for the next frame in a bracket.

Receive state timers

A RSP_TIMEOUT timer is started when a POLL frame is transmitted. The time-out value is larger than the interframe gap time plus the time required to transmit a DATA or EOD frame. If the RSP_TIMEOUT timer expires before an expected response is received, a retry counter is

incremented and a POLL frame with the same SEQ value is retransmitted, if the retry count has not been exceeded.

Each node maintains a receive SEQ state table which has an entry for all nodes which have recently transmitted valid data frames. A receive SEQ state value is reset to 0 when an RFP frame is received, and is incremented when a DATA or EOD frame is accepted. The SEQ state variable is cached in the table so that a source node, which missed a CLEAR response, can inquire as to the status of its last transmission. A CLEAR is (re)sent if a node receives an ENQ and has an entry in its SEQ state table for the source node. A REJECT is sent if an ENQ is received and an entry is not in the table.

The receive state machine uses a routine called "flush" to free any buffers, allocated to a bracket of frames, if an error occurs before the complete bracket is received.

Receive state transitions are specified in table 4.

Medium Access Control

As Tobagi points out in [1], the hidden node problem can severely limit bandwidth utilization in a simple CSMA radio network. Tobagi discusses a channel access technique referred to as **listen-before-talk with busy tone** (**LBT/BT**). LBT/BT requires a second transceiver in each radio-equipped device and a second control channel (i.e. on another frequency) used to broadcast a "busy tone" whenever a node

is actively receiving a radio transmission. For example, in figure 3, if A is transmitting data to B, then B must broadcast a busy tone on the control channel for the duration of the transmission. C is able to sense the busy tone, and refrains from broadcasting to D until the both the data and control channels are idle. The busy tone solution is expensive for obvious reasons. MCNA uses an analogous, but less expensive technique referred to as **busy pulse**. As noted earlier, the DLC component fragments and reassembles network layer packets. A fragment can occupy a channel for a known fixed time period. In figure 5, assume node A is engaged in a bracket transmission with node B. If a third node, C, listens to a radio channel for a worst-case time, t_{bp}, it is guaranteed that it will detect the active conversation if either node A or B (but not necessarily both) is within range of C. The busy pulse technique prevents interrupted conversations by requiring sleeping nodes to listen to the channel for a **busy pulse period** after awakening, before initiating a transmission. The busy pulse period is equal to the time required to transmit a DATA frame plus two interframe gap times. In figure 5, t_{gap} defines the interframe gap time and t_{bp} defines the busy pulse time.

MCNA uses a **channel reservation** technique to generally restrict channel access contention to RFP frames. Each DLC

request frame contains a channel reservation field which indicates the amount of time required to send any outstanding frames in a bracket, without error. The reservation is echoed by the sink in POLL response frames. (Note that the reservation field is always zero in EOD and CLEAR frames.) An LBT algorithm is generally executed only once per conversation. After an RFP frame is sent, the source owns the channel for the entire conversation and subsequent request and response frames can be sent without additional channel access logic. As a result, interframe gap times and, hence, busy pulse times can be well-defined.

Channel reservation can be implemented with a continuous millisecond clock, a RESERVE_TIME variable, and a RESERVE_NODE variable. If RESERVE_TIME is greater than the current millisecond time, the channel is considered reserved and can not be used. The RESERVE_TIME variable is updated when a unicast request or response frame is received as follows: 1) If the destination address in the DLC header is not the local node address and the calculated reserve time of the frame is greater than RESERVE_TIME, then RESERVE_TIME is set to the calculated reserve time and RESERVE_NODE is set to the source address, 2) If the calculated time is less than RESERVE_TIME and the source address is equal to RESERVE_NODE then RESERVE_TIME is set to the calculated time, 3) If the local node address is equal to the

destination address and the source address equals RESERVE_NODE then RESERVE_TIME is set to the current millisecond time (i.e. the reservation is canceled).

Before a unicast conversation or a multicast transmission is initiated, an LBT algorithm is executed to determine if the channel is available. The transmission can begin immediately, if the channel is not active and is not reserved. If the channel is not free, a **random backoff algorithm** specifies backoff delays as a function of the **LBT slot** time and the number of retries. An LBT slot is defined as a function of the best case and worst case busy-sense time. The best case busy-sense time is equal to the amount of time from the point at which a node detected the channel idle, before transmitting, until another node can detect the transmission in progress. The worst cast busy-sense time is best defined by an example. In figure 3, suppose nodes A and C attempt to initiate a conversion with B at approximately the same time. If node A determines that the channel is idle and begins transmitting an RFP frame at time 0, then the worst case busy-sense time is equal to the time t_b, in figure 5, at which node B begins sending a response POLL frame. Node C can not determine that the channel is busy between time 0 and time t_b.

If a channel is detected busy, the access delay time is simply the calculated random backoff time. If a channel is

reserved, a random delay is calculated by adding the reserved time to the calculated random backoff time. Note that the data link layer must continue to monitor link activity during a backoff period.

The backoff algorithm is repeated, whenever a collision is suspected, to randomly distribute retries over an increasing number of LBT slots. The channel access algorithm must assume that a collision may have occurred whenever an expected reply is missed, since **collision detection** (**CD**) is not available. A sink must back off whenever a POLL frame is lost, before it retransmits the POLL frame. A source must back off before retrying whenever an RFP or ENQ frame is lost.

The network layer can indicate to the data link layer that a packet is being sent as a response to a multicast or broadcast message. If a network layer packet is being sent in response to a multicast message, then the data link layer waits for a random delay period before transmitting the response.

The total retry time, including backoff time, at the data link layer must be relatively short so that lost branches in the network layer spanning tree can be quickly detected and new branches quickly re-established.

CHAPTER IV

NETWORK LAYER

Functional requirements

The network layer provides the following functions: 1) The network layer organizes nodes in the network into an **spanning tree** rooted at a **root router node**, hereafter simply referred to as the **root**. The spanning tree is used to prevent loops in the topology. 2) The network layer routes packets along branches of the spanning tree. 3) The network layer provides a service for storing packets for **sleeping** terminals. Packets which can not be delivered immediately can be saved by the network entity in a parent node for one or more HELLO times. 4) The network layer propagates lost terminal node information throughout the spanning tree. 5) The network layer maintains the spanning tree links. 6) The network layer allocates and distributes network addresses. 7) The network layer maintains and provides diagnostic statistics.

Network layer services

The transport layer uses an NL_UNITDATA.request primitive to send a transport layer message. The alias or

network address of the destination node must be passed along with the message. If an alias is passed, the network layer will automatically resolve it into a network address. The alias and associated address are cached in the local network entity. The network header contains several protocol bits which are used to identify data which belongs to a transport layer protocol. When data arrives for a transport protocol, the specified transport protocol entity is notified with an NL_UNITDATA.indication.

Network layer packet definitions

The network header in network layer packets contains a destination address, a source address, and a control word.

Table 5 describes fields in the network header control word. Table 6 describes each of the network layer packet types.

Spanning tree organization

The network layer organizes nodes into a spanning tree with a single router node at the root of the tree. (Note that the LAN ID in the data link header allows more than one logical tree to exist in the same coverage area.) Interior branches of the spanning tree are relatively stable (i.e. controllers and base stations do not move often). Terminals, which are leaves on the spanning tree, may become unattached and must be reattached frequently. All messages

are routed along branches of the spanning tree. Restricting each node in the tree to a single parent guarantees that there will be no loops in the logical topology.

Table 5. Network Header Control Word

PACKET TYPE	This field is used to specify the network layer packet type.
NETWORK PARMS	If this bit field is set ON then optional network layer parameters immediately follow the network header.
RSPRQ	This field can be used to request an end-to-end network layer response packet. Normally this field should be set ON for ATTACH, RARP and ARP request packets, and should be set OFF for all other network layer packets.
PROTOCOL	This field is used to indicate the presence and type of higher layer data.
REQ/RSP	This bit is set OFF in network request packets and is set ON in network response packets.
ATTI	A router node will set this bit ON in an ATTACH.request packet whenever the source node is not in its routing table. The bit value in an ATTACH.response packet follows the state of the bit in the associated ATTACH.request. If a terminal receives an ATTACH.response packet with the ATTI bit set ON, it is a positive indication that the terminal was detached and has reattached to the network.

Table 6. Network Layer Packet Types

DATA	DATA.request packets are general purpose network layer packets used to send higher layer data and/or network layer parameters.
HELLO	HELLO.response packets are used to build the spanning tree and are used to advertise pending message information and lost node information. Scheduled HELLO.response packets are broadcast periodically at calculated time intervals by each router node in the spanning tree. In addition, router nodes will broadcast an unscheduled HELLO.response packet whenever a HELLO.request packet is received.
ATTACH	A node transmits an ATTACH.request packet to attach to the network and to maintain its path in the network. If the RSPRQ bit is set ON the root node will return an ATTACH.response packet. Higher layer data can be piggybacked on ATTACH.request packets.
DETACH	DETACH.request packets are used to notify the network that a node has detached.
ARP	An address resolution packet (ARP) is used to acquire the 16-bit network address of a destination node, when only the alias (or 48-bit identifier) of the node is known. An ARP packet is generated automatically by the network layer whenever address resolution is required.
RARP	A reverse address resolution packet (RARP) is used to set or change the alias and/or 48-bit long identifier of a device and to acquire a 16-bit network address.

Figures 6 and 7 illustrate how physical devices are organized into logical nodes in a spanning tree. Figure 6 depicts devices and the physical communication links. Figure 7 depicts the same devices organized as nodes on

branches of a spanning tree. The root node in figure 7 is labeled with an **R**.

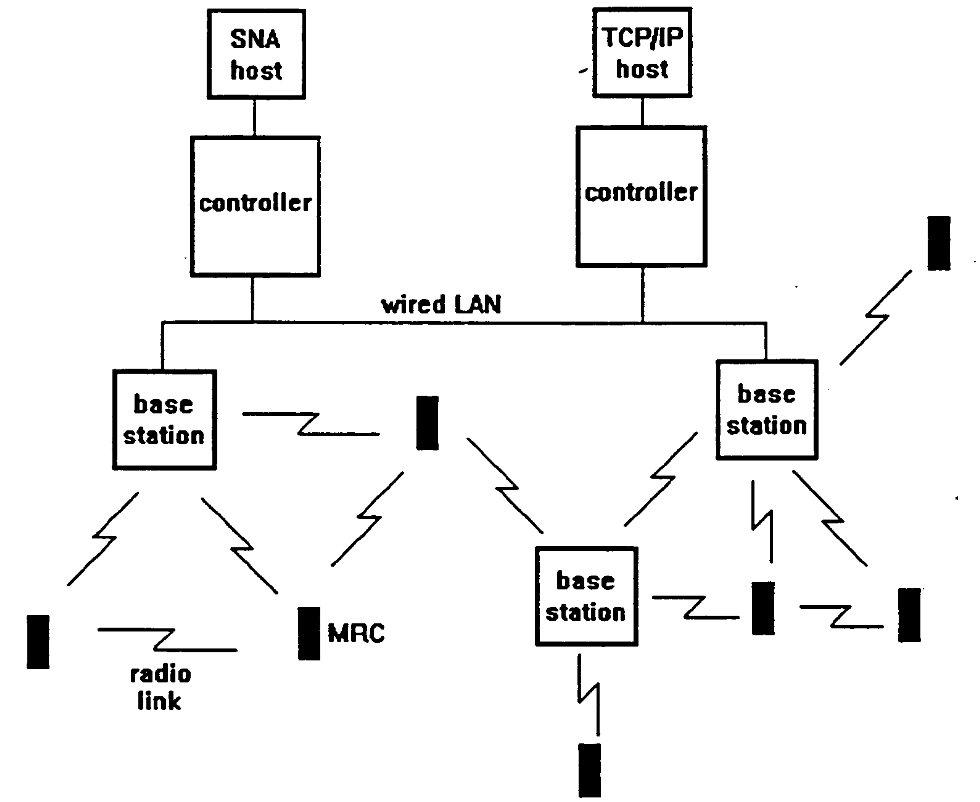

Figure 6. A Block Diagram of Physical Devices and Links

Nodes in the network are generally categorized as **attached** or **unattached** (i.e. to the spanning tree). Initially, only the root is attached. A single controller can be designated to contain the root node, or multiple root candidates can negotiate to determine which node assumes the

root status. The root and other attached router nodes broadcast HELLO.response packets at calculated intervals. The HELLO packets enable unattached nodes to learn the optimum path to the root node before attaching to the network.

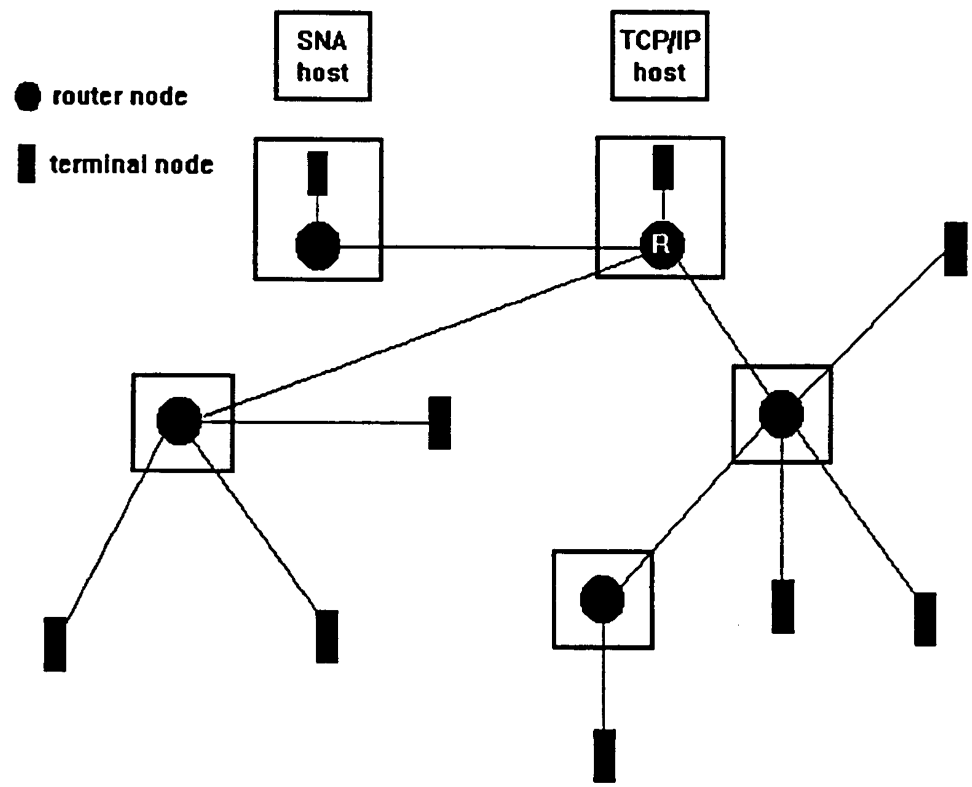

Figure 7. A Spanning Tree

The HELLO.response packets include: 1) the source address; 2) a broadcast destination address; 3) the "cost"

to the root; 4) a "seed" value used to calculate the time of the next HELLO.response packet; 5) a hello displacement time; 6) the priority of the root node (or root candidate); 7) the unique device identifier of the root node (or root candidate); and 8) a root node sequence number, used to distinguish between multiple occurrences of the spanning tree with the same root node.

The HELLO "cost" field indicates the total "distance" to the root, and is equal to the sum of the costs of each hop on the path to the root. (Note that the root node broadcasts HELLO packets with the cost field set to zero.) The incremental cost of the hop between a node and its parent is primarily a function of the physical link type (i.e. ethernet, RS485, or radio). The cost component is intended to bias path selection toward high-speed (i.e. wired) connections. On radio links, spanning tree attachment is biased toward the link with the best signal strength. Signal strength is not a factor in the cumulative path cost.

The HELLO "displacement" field specifies the displacement of the actual hello time from the calculated hello time or to indicate that the hello time was unscheduled. A well-known randomization algorithm is used to calculate the next hello time. The HELLO "seed" field is used as a seed for the calculation.

The "root identifier" and "root sequence" fields are used to define a single instance of the network. Attached nodes must forget their network address and return to the unattached state whenever a HELLO.response packet is received with a new root node identifier or root sequence number.

HELLO.response packets can contain optional parameters such as: 1) a descendent count; 2) a pending message list, and 3) a detached-node list.

A pending message list consists of 0 or more network addresses of sleeping terminals and is used to indicate that a message is pending in the network for each terminal in the list. Pending messages are stored in the parent node of the terminal.

Detached-node lists contain the addresses of terminal nodes which have lost packets or detached from the spanning tree. A router node learns which entries should be in its list from DETACH packets which are distributed throughout the network when a terminal is lost. Detached nodes are included in detached-node lists in HELLO.response packets for DETACH_MSG_LIFE hello times.

Attaching to the spanning tree

Nodes without a parent in the spanning tree are in an UNATTACHED state. In the unattached state, a node learns which attached router node is closest to the root node by

listening to HELLO.response packets. (If no HELLO.response packets are received, the node can wait (i.e. sleep) and retry later.) After the learning period expires an unattached node sends an ATTACH.request packet, with the RSPRQ bit set ON, to the attached router node with the lowest cost to the root. (Nodes without a network address must first send a RARP.request packet to the root to obtain a network address.) The attached router node forwards the ATTACH.request packet onto the root node. The end-to-end ATTACH.request functions as a discovery packet and enables router nodes along the path to the root node to quickly learn the path to the source node. The root node returns the request as an end-to-end ATTACH.response packet. When the unattached node receives the ATTACH.response packet it goes to an ATTACHED state and sets internal **root port** and **parent** variables. (Note that the ATTACH.request must be repeated if an ATTACH.response is not received.) The root port is the physical port on which the response packet arrived and the parent (address) is equal to the data link source address. If the newly attached node is a router node, it calculates its cost to the root, by adding its root port link cost to the HELLO cost of its new parent, and begins to broadcast HELLO.response packets.

Unattached terminal nodes can optionally broadcast a **global** HELLO.request packet with a multicast router

destination address to solicit unscheduled HELLO.response packets from attached router nodes. The net effect is that the UNATTACHED state can (optionally) be shortened. (Note that only attached routers or the root may respond to request packets.) The HELLO.request facility is intended for unattached terminals with transactions in progress.

An attached node can change (i.e. shorten) its path in the spanning tree at any time simply by selecting a new parent and repeating the attach process.

Each attached node must transmit an ATTACH.request or DATA.request packet at least once per ATTACH_TIMEOUT time period to maintain its path in the network. Higher layer data can be piggybacked onto ATTACH.request packets by setting the network layer destination address to the 16-bit address of the node for which the data is intended. If data is piggybacked onto an ATTACH.request packet, the network layer will split the ATTACH packet into separate ATTACH and DATA request packets as soon as the next hop to the destination address is not on the path to the root node (i.e. the first upstream hop). The destination address of the generated ATTACH.request packet is the well-known address of the root node.

Active nodes do not need to explicitly generate ATTACH.request packets. An ATTACH.request is automatically generated (or a DATA.request is converted to an

ATTACH.request), by a router node, whenever a request packet arrives from an upstream node and an entry for the source node does not exist in the router node's routing table. An attach indication (ATTI) bit is set ON in the ATTACH.response packet to notify the source node it has just attached to the network.

Network layer routing

All packets are routed along branches of the spanning tree. Routers "learn" the path to nodes by monitoring traffic from upstream nodes (i.e. traffic directed toward the root). Whenever a router receives a packet from an upstream node, the router creates or updates an entry in its routing table for the source node. The entry includes the node address, and the address of the router which sent the packet (i.e. the hop source address). When a router receives a packet from a downstream node the packet is forwarded to the upstream hop which is specified in the routing entry for the destination. The packet is discarded if a routing entry does not exist.

Packets from upstream nodes are simply forwarded to the next downstream node (i.e. the parent) in the branch of the spanning tree. No explicit routing is required for downstream traffic because the route is defined by the structure of the spanning tree. A packet travels downstream until a node is reached which has an entry in its routing

table for the destination address. The packet is then explicitly routed upstream until it reaches its destination. Thus, terminal-to-terminal communications is accomplished by routing all traffic through the nearest common ancestor of both terminals. In the worst case, the root is the nearest common ancestor.

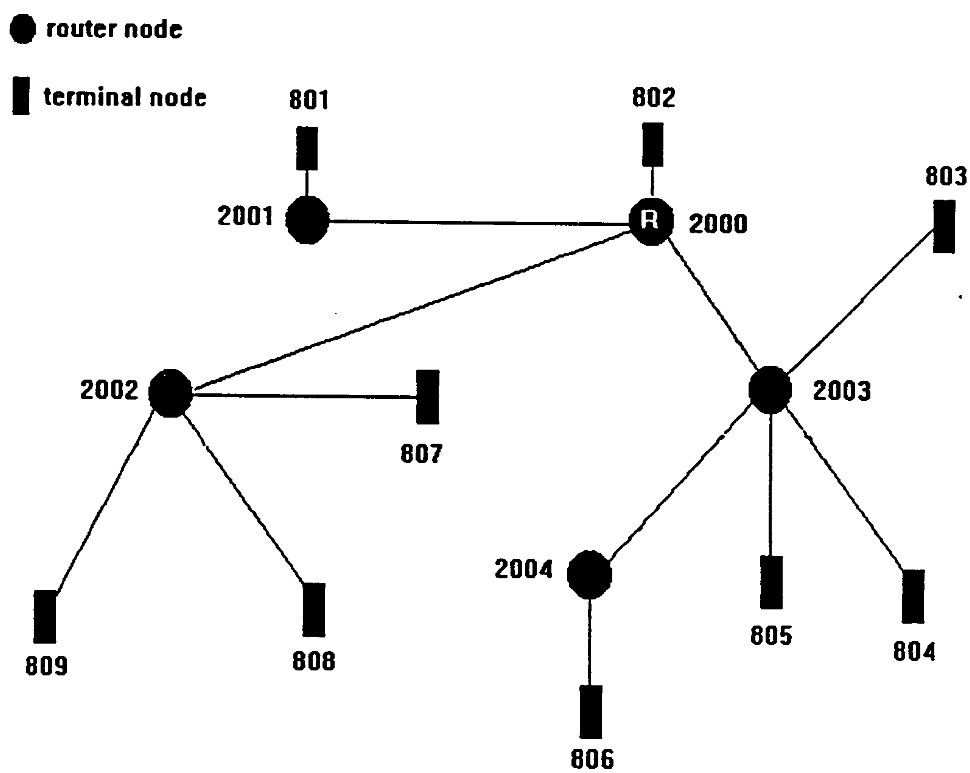

Figure 8. A Spanning Tree with Network Addresses

Figure 8 reproduces the spanning tree from figure 7 along with the hexadecimal address of each node. As an

example, assume terminal 804 sends a packet destined for terminal 806. The packet will follow one downstream hop from 804 to 2003. The routing function at 2003 has an entry for 806 in its routing table which specifies 2004 as the first upstream hop to 806. The packet is routed upstream to 2004. An entry in the routing table at 2004 specifies 806 as the first upstream hop to 806, and the packet is routed from 2004 to 806.

The routing table in each router node defines the subtree rooted at the router node. The routing table for router node 2003 in figure 8 is shown in figure 9 below.

destination	port	first hop	age	child flag
2004	2	2004	1	true
803	2	803	1	true
804	2	804	2	true
805	2	805	0	true
806	2	2004	1	false

Figure 9. An Example Network Routing Table

Routing table entries are created or updated whenever a downstream unicast DATA, ATTACH, or ARP packet is received. If an entry does not exist for the source address in the network header, an entry is created with the destination field set to the network layer source address. The other fields in the (old or new) entry for the destination are

modified as follows: 1) the first hop field set to the source address in the data link header, 2) the port field is set to identify the data link entity which delivered the packet, 3) the age field is set to 0, and 4) if the destination and first hop fields are identical, the child flag field is set to true.

The age field for each entry is incremented at regular intervals. An entry's age field is reset to 0 whenever a packet is received from the destination associated with the entry. If no packets are received from the destination of an entry for ROUTE_TIMEOUT minutes, the entry is deleted from the route table. Nodes can maintain their path in the network by sending an ATTACH.request packet to the root node once every ATTACH_TIMEOUT minutes, where ATTACH_TIMEOUT must be shorter than ROUTE_TIMEOUT.

If a router receives a DETACH.request packet from an upstream router node, then each entry in its route table, with a destination field which matches an entry in the packet's detached list, is deleted.

All nodes, except the root node, keep a **parent** and **root port** variable. A packet traveling downstream is forwarded by setting the data link destination address to the parent address and then passing the packet to the data link entity associated with the root port.

Dynamic changes in the spanning tree

Paths in the spanning tree can change for a number of reasons:

1) Any node may select a new path to the root whenever a better path is found. For example, a better path might be one where the cost of a node's parent from the root is CHANGE_THRESHOLD greater than the cost in a HELLO.response packet from another node. Rapidly moving terminals can cache a short list of alternate parents. Periodically, sleeping terminals, must stay awake for 1 or more HELLO times to discover changes (i.e. shorter paths) in the network topology.

2) A parent node detaches the subtree rooted at a child node, whenever a message cannot be delivered to the child. This occurs when the data link layer in a parent node fails to deliver a unicast network layer packet to a child node.

3) A child node goes into the UNATTACHED state whenever its data link layer fails to deliver a message to its parent. If the child node is a router, it must continue to broadcast scheduled HELLO.response packets with an **infinite distance** for MAX_HELLO_LOST+1 times. If the child node is a terminal, it may solicit unscheduled HELLO.response packets to shorten the UNATTACHED state. After the UNATTACHED learning state has expired the node reattaches by

transmitting an ATTACH.request to the router node closest to the root.

4) If a node in an ATTACHED state receives a DETACH packet or a HELLO.response packet with its network address in the detached list, it must enter the UNATTACHED state and reattach to the spanning tree. (Note that it may not actually be unattached.) After reattaching, the node must remain in a HOLD_DOWN state for MAX_HELLO_LOST+1 hello times. During the HOLD_DOWN state, the node ignores its address in DETACH packet and HELLO.response packet detached lists. After the HOLD_DOWN period expires the node must send a second ATTACH.request to the root, to insure that it is still attached.

5) Entries in routing tables are aged periodically and old entries are discarded. When routing table space for a new entry is required, either an unused entry or the oldest (i.e. least recently used) entry is selected. If a used entry is selected, then the old information is simply discarded.

6) A sleeping node must wake up and enter an ATTACHED listen state whenever a threshold number of HELLO.response packets (i.e. 1 or 2), from its parent, are missed. The state ends when the node receives a data or HELLO.response packet from its parent. The node enters the UNATTACHED state when a) its address appears in the detached list of a

DETACH or HELLO.response packet, or b) a total of MAX_HELLO_LOST consecutive HELLO.response packets are missed.

The time that a node spends in the ATTACHED listen state must be less than the lifetime of detached node information in the network. This insures that a detached node will always enter the UNATTACHED state [i.e. either the node will find its address in a detached node list or the node will miss MAX_HELLO_LOST HELLO.response packets and go into the UNATTACHED state before it sees a "good" HELLO.response packet from its (former) parent].

7) Any node which receives a HELLO.response packet from its parent with an infinite distance immediately enters the UNATTACHED state. If the node is a router, it must continue to broadcast HELLO.response packets with an infinite distance for MAX_HELLO_LOST+1 times.

Note that old invalid paths may exist in the spanning tree for a period of time. For example, if a terminal detaches and reattaches to a different branch in the spanning tree, all downstream nodes in the new branch "learn" the new path to the terminal. Nodes which were also in the old path change their routing tables and no longer forward packets along the old path. At least one node, the root, must be in both the old and new path. A new path is established as soon as an end-to-end attach request packet

from the terminal reaches a node which was also in the old path. Any remaining old path fragment will be disjoint from the new path and will be aged away.

Detach packet logic

Since terminals can be mobile they can lose messages often and must be notified quickly. A router handles lost messages differently for each of the following three cases: 1) the data link hop destination of a lost message is a downstream router (i.e. the parent), 2) the hop destination is an upstream router, or 3)the hop destination is a terminal . In the first case, the upstream router will detach from the network and will begin broadcasting HELLO.response packets with an infinite cost, causing the subtree below the router to detach and reattach to the network. In the last two cases, the router node will generate a DETACH.request packet which includes a detached node list. The detached node list contains the network layer destination address of the terminal which lost the message. Initially, the detach packet is forwarded to the parent node (if it exists) and router nodes which are children. Router nodes which receive a DETACH.request must forward it along all branches of the spanning tree except the branch it was received on. A router node does not forward a DETACH.request if the DETACH.request came from an upstream node, and the upstream node is not the first hop in

the routing table entry associated with the terminal in the detached list. Each router node must broadcast the DETACH.request to all terminal nodes one time so that the terminal can quickly discover that it is detached or has lost a message. In either case, the terminal responds by reattaching to the network. Each router node, which receives the DETACH.request, purges the detached terminal from its routing table and adds the terminal to its detached node set. Detached node information is broadcast in HELLO.response packets for MAX_HELLO_LOST+1 times or until the router determines the terminal has reattached.

Hello synchronization

All attached non-terminal nodes broadcast periodic HELLO.response packets at calculated intervals. On the average, the intervals are separated by HELLO_PERIOD seconds. The HELLO.response packet contains a "seed" field used in a well-known randomization algorithm to determine the next hello time node and the next seed. The address of the transmitting node is used as a factor in the algorithm to guarantee randomization. Nodes can execute the algorithm i times to determine the time (and seed) of the i-th hello packet from the transmitter.

After attaching, a router chooses a random initial seed and hello time and broadcasts a hello packet. The router chooses succeeding hello times by executing the

randomization algorithm. If the transmission of a HELLO.response packet is delayed, then the delay is entered into a "hello displacement" field in the packet, so that the calculated time can be accurately derived by a receiver. Cumulative delays are not allowed (i.e. contention delays during the i-th hello transmission do not effect the time of the i+1 hello transmission).

Sleeping terminal support

A sleeping node initially "synchronizes" on a HELLO.response packet from its parent. The node can calculate the time of the next expected HELLO.response packet from its parent and can power-down with an active timer interrupt set to wake it just before the HELLO.response packet is transmitted. The network layer entity in a parent node can store a message for a sleeping node until the node "requests" the message by notifying its parent that it is awake. A terminal learns that it must request unsolicited saved message by examining the pending message list in the HELLO.response packet. This implementation enables sleeping terminals to receive unsolicited messages and relaxes the timing constraints for transaction oriented messages.

ATTACH, DATA, and ARP request packets can contain several network parameters which are used for storing **pending messages** for sleeping terminals in the parent router

node. A "delivery service type" parameter, indicates that a terminal (i.e. which sent the request) is sleeping. An "awake time window" parameter is used to specify an awake time period. An "awake time offset" parameter is used to specify the start of the awake time window. (The awake time window is effective immediately if an awake time offset is not specified.) An "auto awake" delivery service type can be used to implicitly set an awake time window each time the parent node receives a message from the sleeping terminal. A "maximum stored message count" field specifies the maximum number of HELLO times that a message should be stored in the parent router node. The network layer entity in a parent node will store pending messages until 1) the message is delivered, or 2) "maximum stored message count" hello times have expired.

Address Resolution

An address server in the root node maintains network addressing information in an address table, distributes network addresses to requesting nodes, and resolves network addressing problems. Each entry in the address table contains a device type field, a network address field, a long ID field, an alias field, an in-use field, and an age field. Entries in the table are aged so that they can be reused after MAX_ADDRESS_LIFE minutes. Aged entries are kept in the table indefinitely. The age field in an entry

is reset to 0 whenever a RARP.request or ATTACH.request packet is received from the node associated with the entry.

A separate sequential set of unique node identifiers is maintained for router nodes and terminal nodes. Each set begins with an identifier of 1 and ends with the maximum range for the device type.

Reverse Address Resolution Protocol (RARP)

A RARP.request packet can be used to: 1) acquire a network address from the address server, 2) change an existing 48-bit long identifier in the address table, or 3) change an existing alias in the address table.

A node which does not yet have a unique 16-bit network address must request a 11-bit node identifier from the address server. The node uses a multicast address until a unique node identifier is assigned. A RARP.request packet, containing the requesting node's unique 48-bit long identifier and/or an alias, is sent to the address server by the requesting node. When a node requests a new address, the server first checks its address table to determine if the node already has a (valid or aged) address. If the node doesn't already have an address, the server allocates the next available node identifier, for the device type, to the node. In either case, if an address is available, the server will set a network address field in the RARP packet to the allocated address and will set a RARP return code to

0. If an address is not available, or an entry already exists in the address table with ambiguous identifiers, the address server will set the network address field to all 1's and will indicate the error in the return code field.

The address servers returns the RARP.request packet to the requesting node as a RARP.response packet. If the node, which generated the RARP.request packet, does not receive a RARP.response packet within PATH_TIMEOUT seconds, it must resend the RARP.request.

RARP routing

RARP packets can not be routed with regular routing tables because a node does not have a unique network address until it receives a RARP response packet. Each router node maintains a separate RARP routing table which contains entries for upstream nodes which have recently sent a RARP.request packet to the root node. An example RARP route table is shown in figure 10.

Whenever a RARP.request packet is received, an entry is created (or updated) in the RARP route table and the long ID and/or alias fields in the entry are set to the values specified in the request packet. The node which initiated the request is defined by the long ID and/or alias. The return code is initialized to "invalid" to indicate that an associated RARP.response packet, destined for the node which originated the RARP.request, has not been received. The

port field points to the port on which the RARP.request was received. The network address is set to the network layer source address of the RARP.request packet. The default global node identifier (i.e. all 1's) is used before a unique network node identifier is obtained. (If a node is attempting to change its long ID or alias, then the network address may be unique.) The first hop field will be set to the MAC source address. The age field will be set to 0.

long ID	alias	port	first hop	network address	return code	age
hex 1003508A990C	null	1	hex 020A	hex FFFF	invalid	0
hex 1003508A920B	term2	1	hex 87FF	hex 080C	0	3

Figure 10. An Example RARP Routing Table

Normally, a router node will forward RARP.request packets to the root node. However, if a router node receives a RARP.request packet, and a valid entry for the node which initiated the request is already in the RARP route table, the router can simply return a RARP.response packet to the source node.

When a router node receives a RARP.response packet from the root node, it will update the return code and network address fields in the RARP route table entry for the node

which initiated the request. RARP.response packets are forwarded on the port specified in the route table entry. The MAC destination address is set to the first hop address. Note that the last hop is often made with a broadcast transmission.

RARP route table entries are aged (quickly) so that older entries are discarded in RARP_TIMEOUT seconds.

Address Resolution Protocol (ARP)

A node can request the 16-bit network address of another node by sending an ARP.request packet to an address server in the root node. The ARP.request packet must contain either the 48-bit identifier or the alias of the target node, but not both. The address server returns the 16-bit network address of the target node in an ARP.response packet, if the target node exists in the server's address table. An address of all 1's and an error is returned if the target node is not in the address table or if the entry for the target node is aged.

Address maintenance

A node will lose its address if: 1) the root node changes (i.e. either a different ROOT ID or root sequence number is detected in a HELLO.response packet); 2) it has not received an ATTACH.response packet, from the root node,

within an ADDRESS_TIMEOUT time period; or 3) no network activity is detected within a NETWORK_TIMEOUT time period.

A node can maintain its address by sending an ATTACH.request packet to the root node at least once per ADDRESS_TIMEOUT time period. Note that a node must send an ATTACH.request to the root at least once per ROUTE_TIMEOUT time period, to maintain its path to the root in the spanning tree; therefore no special logic is required for address maintenance. If the node is active it can simply piggyback the ATTACH.request on a higher-layer downstream data packet. The root node will return an ATTACH.response packet, and the node can reset its ADDRESS_TIMEOUT timer when the response packet is received.

Root resolution

Root resolution states

The network layer entity in each router node is in one of the following high-level **node states**:

R - Root node. The node owns the root node address.

RC - Root candidate node.

NR - Router node which has a non-zero root priority.

An 'a' subscript is used to denote nodes without a network address.

All node states are further qualified by one of three **attach states**:

D - The node is **D**isabled and unattached.

U - The node is enabled and **U**nattached.

A - The node is enabled and **A**ttached to the network.

I - The node is in an **I**ntermediate hold-down state.

For example, RC.U, is used to denote the node and attach state of a root candidate which is not attached to the network.

The following substates are used to qualify an unattached node:

idle - No network activity has been detected.

wait - Wait for the first HELLO.response packet.

hello - A HELLO.response packet has been received.

Each MCNA network must have one or more root candidates. Each root candidate node enters the RC.U state when the network layer entity in the node is enabled. This state ends when 1) the root candidate determines that a higher priority root node already exists and enters the NR.U state, or 2) the root candidate assumes ownership of the root node status and enters the R.A state. A node in any NR

state assumes the root node status if 1) the network becomes idle, or 2) a lower priority root node is detected.

A root candidate which does not detect any activity assumes the root node status. If activity is detected, the root candidate remains in the RC.U.wait state until a HELLO.response packet is received or until network activity ceases.

In the R.A state the root node broadcasts a HELLO.response packet once per HELLO_PERIOD time period, according to a random distribution algorithm. The root HELLO.response packets contain a path cost of 0, the priority of the root node, a root sequence number, and a ROOT ID which is either the unique long identifier or the unique alias of the root device. <u>The priority, root sequence, and ROOT ID fields are copied into the HELLO.response packets transmitted by all non-root routers in the network</u>. The root sequence number is stored in non-volatile storage by all root candidates. The sequence number is copied into RAM by the root node when it determines that it is the root and the copy in non-volatile storage is incremented.

Hello packet priority

A "higher priority HELLO.response packet" is defined as any HELLO.response packet which contains a matching LAN ID and either 1) a higher ROOT PRIORITY field, or 2) an equal

priority field and a higher priority ROOT ID. A ROOT ID can consist of a unique 48-bit device ID and/or a device alias. A "higher priority ROOT ID" is defined as 1) the ID with the higher 48-bit ID, or, 2) if neither candidate has a 48-bit ID, the ID with the alias with highest string value. Note that if the ROOT ID does not contain a unique 48-bit device ID, then the 48-bit device ID is assumed to be all 0's.

It may be possible for a root candidate to receive a HELLO.response packet with an equal priority if the ROOT ID field in the HELLO.response packet matches the candidate's device identifier. Received HELLO.response packets with a ROOT ID field that matches the identifier of the local device and a non-zero path cost are assumed to be associated with an out-of-date spanning tree and are discarded by the network layer. Received HELLO.response packets with a matching ROOT ID and a zero path cost cause a fatal error.

The state transition table below defines transitions in the root resolution process.

Table 7. Root Resolution State Transition Table

state	event	action	next state
RC.D	Network layer entity enabled.	Enable data link layer on all network ports; set HELLO_TIMEOUT inactivity-timer.	RC.U.idle
RC.U.idle	Inactivity-timer expires.		R.A
	Non-HELLO packet received.	Set R_IDLE_TIME inactivity-timer.	RC.U.wait
	Higher priority HELLO packet received.	Set R_IDLE_TIME inactivity-timer; set HELLO_TIMEOUT hello- timer.	NRa.U.hello
	Lower priority HELLO packet received.		R.A
RC.U.wait	Inactivity-timer expires.		R.A
	Non-HELLO packet received.	Set R_IDLE_TIME inactivity-timer.	RC.U.wait
	Higher priority HELLO packet received.	Set R_IDLE_TIME inactivity-timer; set HELLO_TIMEOUT hello- timer.	NRa.U.hello
	Lower priority HELLO packet received.		R.A
NR.U	Lower priority HELLO packet received.	Set R_IDLE_TIME inactivity-timer.	NR.I then RC.U.wait
R.A	Higher priority HELLO packet received.	Transmit HELLO packets with an infinite path cost for MAX_HELLO_LOST+1 HELLO periods; set R_IDLE_TIME inactivity-timer; set HELLO_TIMEOUT hello-timer.	R.I then NRa.U.hello

CHAPTER V

TRANSPORT LAYER

The MCNA transport layer provides a reliable connection oriented service and an unreliable connectionless service. The MCNA network layer does not provide a reliable end-to-end service because it can lose packets over transient radio links. **Go-back-n** transport error recovery is sufficient since the network layer does not fragment packets and packets are normally delivered in sequence. The transport layer recovers from lost packets, discards duplicate packets, and fragments and reassembles logical user messages. Essentially, it provides a data pipeline between access points in terminal nodes.

Connection oriented services are provided with the following primitives:

```
TL_CONNECT.request(alias,DSAP, . . .)
TL_CONNECT.indication(destination,DSAP,SSAP, . . .)
TL_LISTEN.request(SSAP, . . .)
TL_SEND.request(connection, buffer, length)
TL_RECEIVE.indication(connection, buffer, length)
TL_DISCONNECT.request(connection)
```

Connectionless services are provided with the following primitives:

```
TL_UNITDATA.request(alias,DSAP,SSAP, buffer, length);
TL_UNITDATA_LISTEN.request(SSAP,...);
```

A transport connection is defined by a destination and source network address and a destination and source service access point (SAP). The TL_CONNECT and TL_LISTEN functions are used to establish a transport connection between two service access points. A transport application in a first node can use TL_LISTEN to "listen" on a well-known source service access point (SSAP). A transport application in a second node can "connect" to the well-known access point with the TL_CONNECT function. The TL_CONNECT.request DSAP parameter is the same as the SSAP parameter used in the TL_LISTEN.request. A connect SSAP is generated by the system in the second node. The "alias" passed to the TL_CONNECT.request function is the network name of the first node. The network layer converts the alias into a network address. Once a connection is established, data is sent and received with the TL_SEND.request and TL_RECEIVE.indication functions. A node which initiates a connection must insure that at least a MAX_PACKET_LIFE time period has expired

since an old connection existed before issuing a new TL_CONNECT.request with the same alias, DSAP, and SSAP.

Since all packets sent during a connection may not follow the same path, no more than MAX_SEQ frames may be sent in a MAX_PACKET_LIFE time period, where MAX_SEQ is the maximum message sequence number and MAX_PACKET_LIFE is the longest time that a packet can be delayed in the network. Note that the spanning tree topology insures that packets will not loop.

The transport entity in a terminal node stores messages for possible retransmission. Retransmissions may not always follow the same path, as the original transmission, due (primarily) to moving terminals and the resulting changes in the spanning tree. For example, the network layer entity in a parent node may disconnect a child after the data link entity reports a message delivery failure. The child will soon discover that it is detached and will reattach to the spanning tree with a different parent. Now when a transport layer message is (re)sent, it will follow the new path.

Network packets can be lost due to terminal roaming or network congestion. In a congested network a packet can be discarded by a router node when the router does not have a free buffer. A timer is started for each transmitted transport message which requires a response. If the expected response is not received within a reasonable time

period, the message is retransmitted. Retransmitting discarded messages too quickly can aggravate the congestion problem. The MCNA transport layer uses an adaptive timer algorithm to adjust the expected propagation delay for transport messages to the end-to-end distance and traffic load, without causing sporadic changes or dramatic swings in time-out values. The algorithm prevents the transport layer from saturating the network by increasing message time-out values (i.e. increasing the time between retransmissions) whenever a message is lost. The algorithm prevents saturation when the network is congested but reduces response times when messages are lost due to roaming terminals. To alleviate this problem, the MCNA network layer notifies the transport layer when a network layer path change is detected. The notification can trigger an immediate retransmission if unacknowledged messages exist on a connection, or an expected response has not been received.

Since network addresses are a component of a transport connection identifier, the transport entity in each node must be notified when the root node changes. Old network addresses are invalid if the root node changes and the associated transport connections are lost.

A separate trivial transaction-oriented transport protocol (TTTP) is required to reliably gather network statistics and to send mail messages between terminals.

TTTP allows information to be reliably exchanged between nodes without the overhead of creating and deleting connections. TTTP requires a response at the application layer and retries transaction requests until a response is received. All transactions are assumed to be idempotent.

CHAPTER VI

SUMMARY

Conclusions

The MCNA backward learning technique eliminates the need to broadcast or exchange routing information. Roaming terminal nodes can switch paths immediately with little added overhead. A disadvantage of the backward learning technique is that a terminal node can not directly communicate with another terminal node. All data traffic must be routed through the nearest common ancestor, thus increasing the total data traffic in the network. MCNA assumes that most of the extra traffic can be localized to high-speed wired links. This is certainly a valid assumption if the predominant application is terminal emulation, since most traffic is directed to a host computer.

An MCNA network is inherently redundant. If a router node fails, the subtree underneath it can quickly re-attach to the network, with minimum overhead, provided a coverage area is not lost. If the root node is lost, the root

resolution protocol enables another node to assume the root status and the spanning tree can be re-built.

MCNA provides an efficient and robust solution for connecting a periphery of mobile terminals to a stable network infrastructure.

Future MCNA extensions

MCNA requires a hierarchical network for communications between any two nodes. A desirable extension, would be to allow two MCNA nodes to communicate directly in the absence of the hierarchical network. Such point-to-point sessions are often referred to as **ad hoc conversations** in current papers on wireless networks. A problem arises because data link and network addresses are dispensed by the MCNA network. This problem could be overcome by defining a global LAN identifier, reserved for ad hoc conversations, and by allowing nodes to independently choose data link addresses as part of an initial handshaking phase prior to an ad hoc session. Predefined unique network addresses (i.e. IEEE 802 addresses) could be assigned to each MCNA node to avoid problems arising from ambiguous data link addresses. Note that the use of predefined (i.e. large) data link addresses would add substantial overhead for unicast transmissions.

As a second possible extension, the MCNA architecture could be modified to enable transparent bridging to wired

802 local area networks. Such an extension requires each node in the MCNA network to be identified by an IEEE 802 address. The device which contained the MCNA root node would have to function as the designated bridge for the "MCNA subnet". The details of this extension are beyond the scope of this thesis and are the subject of a patent application submitted by Norand Corporation.

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Cancelled per Query Response 4-25-02

APPENDIX B:

TM 1100 DATA TERMINAL SPECIFICATIONS

980–000–096
April 1993

NORAND®

service
instruction book

TM1100
Data Terminal

This instruction book is in four sections:

General Information

Theory of Operation

Maintenance

Diagrams and Parts Lists

1.1 INTRODUCTION

This service instruction book (SIB) contains the theory of operation, maintenance procedures, and diagrams and parts lists for the NORAND® 1100 Series Data Terminal (NPN 225–001–XXX). The 1100 Series Data Terminal is shown in Figure 1–1. Refer to table 1–1 for the terminal specifications.

1.2 PURPOSE OF EQUIPMENT

The 1100 series terminal is a portable, hand–held computer terminal. It is used in various NORAND data networks as a data gathering device. The operator enters data into the terminal using the terminal keyboard, an attached bar code scanner, an integrated barcode scanner, or a combination of the three. The terminal transfers the entered data to a host computer over a radio frequency link or through a local area network (LAN), via the remaining components of the network.

The 1100 Series Data Terminal contains 512K of non–volitale RAM, 128K of FLASH and 512K of masked ROM memory.

The terminal uses a variety of attached (as opposed to integrated) five volt bar code scanning devices. Attached bar code scanners are connected to the terminal at the 9–pin D–sub connector located on the bottom of the terminal. The terminal controls the operation of the scanner.

Terminals with integrated bar code scanners have a built–in scanning device. Integrated scanning terminals feature four "triggers" to operate the scanner – two on the integrated bar code scanning device, and two on the terminal keypad.

The terminal display is a 4–line by 16–character, reflective super–twist LCD. The reflective super–twist LCD enhances the display's readability, even in low lighting.

The terminal keypad has 47 alphanumeric keys, includng the ON/OFF key. Four keys are programmable in both the normal and shift modes, for a total of eight special characters or function .

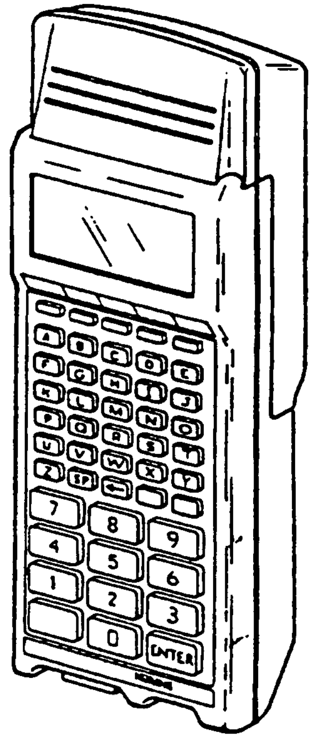


Figure 1–1
1100 Series Data Terminal (RT1140 model shown)

1.3 COMMONLY USED ABBREVIATIONS

Table 1–2 lists the abbreviations used throughout this service instruction book.

Table 1–1. *RT1100 Data Terminal Specifications (continued)*

CHARACTERISTIC	SPECIFICATION
External Connectors	
Scanner linterface:	9–pin D subminiature
J2–1	SOS
J2–2	DATA
J2–3	LED
J2–4	MOTORFAIL
J2–5	TRIGGER
J2–6	ENABLE
J2–7	GND
J2–8	GND
J2–9	+V
RS232/485	6–pin mini–DIN
J1	ERXD/DATA
J2	ETXD/DATAL
J3	RTS
J4	CTS
J5	CHG
J6	GND
Charger:	6–pin DIN
J3–1	NOT USED
J3–2	NOT USED
J3–3	NOT USED
J3–4	GND
J3–5	CHARGE
J3–6	NOT USED

Table 1–1. *RT1100 Data Terminal Specifications (continued)*

CHARACTERISTIC	SPECIFICATION
Flextail Callouts	
P3–1	ENABLE
P3–2	SSOS
P3–3	GND
P3–4	SDATA
P3–5	GND
P3–6	SCNLED
P3–7	VSCAN+
P3–8	GND
P3–9	TRIGGER
P3–10	ERTSA
P3–11	CHARGE
P3–12	ERXDA
P3–13	ETXDA
P3–14	ECTSA
P3–15	GND
Radio Transceiver	
J1–1	GND
J1–2	SW B+
J1–3	XMIT B+
J1–4	RX +5
J1–5	TX +5
J1–6	TX MOD
J1–7	SQ DET
J1–8	SQ ADJ OUT
J1–9	SQ ADJ IN
J1–10	DISCR OUT
J1–11	CH SEL B
J1–12	CH SEL A

Table 1–2 *Commonly Used Abbreviations*

ABBREVIATION	MEANING	COMMENTS
A	Ampere	Unit of measurement for electrical current.
ac	Alternating Current	Current that periodically changes magnitude and direction of flow.
aux	Auxiliary (backup)	
cm	Centimeters	
CMOS	Complementary Metal–Oxide Semiconductor	
CPU	Central Processing Unit	Circuit which contains a microprocessor. Can also designate the microprocessor itself.
dc	Direct Current	Current which always flows in the same direction.
EEPROM	Electrically Erasable Programmable Read–Only Memory	Medium for permanent storage of operating program.
EPROM	Erasable Programmable Read–Only Memory	Medium for permanent storage of operating program.
ESD(S)	Electro Static Discharge (Sensitive)	Voltage induced into equipment by static charges present in most work/lab environments. (Units or subassemblies that may fail when subjected to electrostatic charges.)
FM	Frequency Modulated	Method of integrating data onto an RF carrier signal.
Hz	Hertz	Unit of frequency measurement. 1 Hz = 1 cycle per second.
I/O	Input/Output	Data going to (input) or coming from (output) a device or component.
in	Inches	
k	kilo	One thousand (e.g., kV = 1 thousand volts).
LCD	Liquid Crystal Display	
m	milli	A thousandth (e.g., mV = 1 thousandth of a volt).
max	Maximum	
min	Minimum	
mux	Multiplexer	
NPN	Norand Part Number	

2.0 General

This section contains the theory of operation for the TM1100 Data Terminal. The TM1100 terminal is positioned toward the high end of the Cricket family of portable data terminals with a 16–bit 8086 compatible microprocessor, program and data memory, radio/scanner expansion modules that are compatible with the RT1000 and new expansion modules with increased functionality.

2.1 TM1100 Functionality

The TM1100 terminal shares a number of characteristics with the RT1000 terminal including its battery pack, 47 key keyboard, moving beam scanner interface, compatibility with the RT1000 radio/scanner expansion modules and a slightly modified version of the plastic case. The primary differences between the TM1100 and the RT1000 terminals are in the areas of processor intelligence, memory capacity and peripheral connection capability.

The TM1100 has an 80C188EB microprocessor as its main data processing unit with 512K bytes of masked ROM, 512K bytes of RAM and up to 256K bytes of Flash EPROM. This processor and memory combination allow significant application program functionality to be resident within the terminal including "IBM PC–like" DOS, "C", and other personal computer derived programming methods.

The TM1100 LCD display is also substantially different from the RT1000 type. A single integrated circuit graphic display controller is assembled with the LCD glass and electroluminescent backlight panel into a module form. The display format is a graphic type with 48 rows x 100 columns which form 6 lines of 16 5x7 dot matrix characters with the remaining 4 pixel columns used for icon style annunciators. The display is backlighted by an integral electroluminescent panel which is powered by high voltage AC drive circuits on the main circuit board.

Other areas of expanded functionality in the TM1100 include its RS–232 and RS–485 interface capability, battery backed RAM and real time clock, and its unique combination of two microprocessors which partition the terminal operation requirements into the two parts of I/O and power management which is controlled by an H8/325 microprocessor and application processing which is the function of the 80C188EB microprocessor. This combination provides improved power conservation while maintaining the necessary processing performance for popular programming and application development environments. Much of the terminal functionality is included in a custom LSI circuit (ASIC) which implements the memory interface, processor and real time clocks, interprocessor communications and backlight drive control.

2.2 System Block Diagram Overview

The TM1100 Data Terminal is a microprocessor based terminal with features that allow it to be used and programmed similarly to popular personal computers. The block diagram of the terminal is shown in Figure 2–1, on page 2–2.

The main CPU is an Intel 80C188EB microprocessor which is a 16–bit microprocessor with on–chip interrupt interface, I/O ports, timers and serial interface.

The I/O and power management processor is a Hitachi H8/325 single chip microcontroller with 32K bytes of on–board masked ROM, 1024 bytes of RAM, serial interface, timer/counters and external I/O ports.

The ASIC provides a parallel communication path between the two processors using back–to–back memory mapped ports that allow data

to be written by one processor and read by the other. The ASIC also includes the bus demultiplexing circuits for the 80C188EB as well as memory decoding and processor clock generation.

The memory organization of the terminal is a combination of masked ROM, Flash EPROM and pseudostatic RAM. The pseudostatic RAM and real time clock in the ASIC are powered by a backed up power supply.

The liquid crystal display is a module featuring a 48 line by 100 pixel graphic format with an integral LSI driver/controller integrated circuit and electroluminescent backlight panel. The display is interfaced to the 80C188EB processor through memory mapped I/O. The keyboard is directly interfaced to the H8/325 processor by processor ports. A radio module is interfaced to the H8/325 with processor ports and the H8/325 serial interface. Expansion modules of types other than a radio module are interfaced to the H8/325, however, a high speed serial interface facility to the 80C188EB is available for direct coupling. This may be useful for interface to devices that require high data rates such as solid state disk modules or certain high speed radio modules.

Externally attached or integrated scanners are interfaced through ESD protection circuits to processor ports. The power control block consists of the terminal battery and power control and voltage regulator circuits.

2.3 Application Microprocessor

The main processor in the TM1100 is an 80C188EB which is a highly integrated fully static low power 16–bit microprocessor featuring an 8086 compatible instruction set with an 8–bit external data bus, chip select generation logic, 3 counter/timer units, two serial communication ports, I/O ports, a power management unit and an interrupt controller unit. Since the 80C188EB is a fully static device, the clock may be turned off completely without losing its state resulting in significant power savings.

2.4 Memory

2.4.1 Masked ROM

The masked ROM is a 512K byte device which contains two basic blocks of information. The bootstrap loader which controls loading and programming of the Flash EPROM is contained in the masked ROM so that there is a guaranteed ability to initialize or restore the condition of the terminal under conditions ranging from manufacture to fault recovery. The other information stored in the masked ROM is the character generator used by the 80C188EB to form characters in the graphic display. This character generator contains the so–called "shift–JIS" character set which includes a complete set of international text characters as well as a 6500 character Japanese Kanji symbol set. Initial TM1100 units will use an OTP (One Time Programmable) EPROM device until the masked units are available.

2.4.2 Flash EPROM

The Flash EPROM is a 256K byte device which contains stored system and application programs. Flash EPROM is a technology similar to the ultraviolet erasable EPROM except the erase function is performed electrically. Consequently, there is no need to remove the device from the circuit for reprogramming so the device can be directly soldered to the circuit board. The Flash EPROM is the primary application program storage location. The masked ROM contains a bootstrap load and Flash programming utility that is used to re-

The display is backlighted by an integral EL panel which is driven by high voltage AC drive circuits located on the CPU circuit board.

2.7 Keyboard

The TM1100 terminal has 47 keys including the power–on key. The keyboard is organized as a crosspoint matrix in 8 row x 6 column format and is interfaced to the H8/325 microcontroller. The row lines are connected to processor outputs and the column lines are connected to inputs with pullups. Keyboard scanning is accomplished by sequentially driving a single row line low and reading the column lines to determine when one of those lines is low. The indicated line corresponds to the column in which the activated key is located, so the key is located by the junction of the selected row line and the indicated column line. Since the key is a switch, there is switch bounce associated with the electromechanical contact, so a firmware routine is included to deal with the switch bounce effects.

2.8 Expansion Interface

As a member of the Cricket product family, the TM1100 terminal has been developed initially to be a radio data terminal. However, with the significant application program and data storage capability of the terminal, it is clear that the TM1100 has excellent capacity to be used as a site–based batch terminal as well. Consequently, the RT1000–style modular radio interface has become a much broader concept in the TM1100.

2.8.1 Radio Interface

Radio communication in the TM1100 includes the RT1000 style radio module for UHF applications as well as an expanded radio module for Spread Spectrum (SST) communications. As in the RT1000, the UHF communication capability is built around the Motorola Radius P10™ and P60™ radio transceivers. The H8/325 processor handles UHF radio communications completely including power control to the radio module, receiving and transmitting characters, and complete implementation of the radio protocol. When a complete, error free block of information is received and contained in the H8/325 memory, it "wakes up" the 80C188EB processor and transfers the block at high speed, thereby significantly reducing the amount of time that the 80C188EB has to be powered and operating. Transmission of a block of information is handled in a similar manner, with the 80C188EB transferring a block to be transmitted to the H8/325 memory and powering off while the H8325 performs the radio communication function.

SST communication is handled somewhat differently in the TM1100 due to the high data rate and HDLC format of the SST radio. Because of this somewhat unique communication requirement, the SST radio module has its own self–contained microcontroller, Serial Communication Controller (SCC) and counter/timer circuit imbedded in a digital ASIC which also includes the digital circuits required by the SST radio itself. The SST radio module with its processor and ASIC handle the SST communications and protocol completely and transfer received and transmitted data directly to and from the 80C188EB processor. As in the case of the UHF module, power is conserved by using a low power processor to perform the communication and protocol handling function.

2.8.2 Scanner Interface

The TM1100 has the capability to support a variety of attached or integrated scanners. Interface to scanning devices is shared betwee

generally used for networked interface connections where the multidrop capability is needed.

2.8.4 ASIC

A digital Application Specific Integrated Circuit (ASIC) is used to implement a significant portion of the logic functionality of the TM1100. The ASIC includes the back–to–back 8–bit ports that are used by the 80C188EB and H8/325 microprocessor to communicate with each other, bus demultiplexing, memory decoding and control for the 80C188 ROM, Flash EPROM and pseudostatic RAM, drive and control for the electroluminescent backlight high voltage generation circuit, clock oscillators for both microprocessors and the battery backed real time clock.

2.8.5 Power Control

The TM1100 is powered by a standard Motorola P10™ 7.2 volt NiCad battery pack or equivalent. The terminal is powered on and off by a momentary contact SPST power–on key which toggles a latch to control power. The terminal 5 volt operating power is generated by a voltage regulator with an external pass transistor. The negative voltage required by the LCD is generated by a charge pump driven by the digital ASIC. Backup power for the real time clock and pseudostatic RAM is provided by a 0.3 Farad supercap and a low power voltage regulator. Battery charging is accomplished by a constant current regulator. The battery and charge voltage are monitored by the H8/325 using its pulse width modulator outputs to create an analog voltage that may be used in a successive approximation analog to digital conversion.

2.9 Detailed Description

The following paragraphs describe the operation of the 1100 terminal in detail. Component names and reference designators used in the following paragraphs match those used in the schematic diagrams of the 11000 terminal, contained in the Diagrams and Parts List section of this book.

2.10 Processor

The heart of the TM1100 is the 80C188EB microprocessor U9 with its high speed, high integration and 8086 compatible instruction set. With the 80C188EB as its core, it is possible for application programs to be developed for the TM1100 in a manner similar to that used by popular personal computers such as the IBM–PC.

Power–on reset of the TM1100 is controlled by the H8/325. Specifically, the reset signal **RESC188** is generated by the H8/325 U10 pin 31 and is applied to pin 68 RESIN of 80C188EB U9.

The 80C188EB U9 pin 71 is clocked with a digital clock signal **OSC_16MHZ** that is derived from an 18.432 Mhz crystal oscillator and is gated and driven by U3 74HC02 pin 1 through resistor R22 392Ω. When the 80C188EB is placed in its shutdown condition, the **OSC_16MHZ** signal is gated off to reduce power consumption. The 80C188EB divides this clock input by 2 for a net processor execution cycle speed of 9.216 Mhz.

Since the 80C188EB employs a multiplexed address/data bus, it is necessary to demultiplex the bus by latching the address information on the bus with the falling edge of the ALE signal pin 38 of U9. This function is performed by the ASIC U6 which receives the multiplexed address/data bus on the lines DB0–DB7 and outputs the address information on the lines

port which will be described in more detail in section 3.13, while serial port 1 is used for high speed communication to the peripheral expansion unit, which is often a radio module but may be some non–radio unit such as a modem, solid–state disk, automatic identification interface or some other type of peripheral interface. This high speed interface uses the 80C188EB RXD1 and TXD1 signals to drive the **RXDC188** and **TXDC188** signals respectively to the expansion module. These high speed signals will normally be connected to and interpreted by a separate microprocessor in the expansion module.

Two of the 80C188EB on–board high speed 16–bit timer/counter units are be used to capture the relative widths of bars and spaces as detected by bar code scanners of either attached or integrated type. The scan data signal **DATA** representative of bar and space widths is connected to T0IN U9 pin 76. The complement **DATALOW** is generated by an inverter in the ASIC U6. **DATA** is connected to the ASIC U6 pin 30 and **DATALOW** is generated at U6 pin 29. **DATALOW** is then connected to the 80C188EB T1IN timer/counter input U9 pin 78. By tying the scan **DATA** signal and its complement to two separate timer/counter inputs, it is possible to operate the timer/counters in gated count mode which generates count values proportional to bar and space widths that may be interpreted by the scan decode algorithms. **DATALOW** is also connected to processor port P2.5 U9 pin 4 so its level may be monitored to identify the presence of a wand scanner. For a more detailed description of the scanner interface and control operation, see section 3.9.

A number of the control and interface signals necessary for the operation of the TM1100 terminal are generated by 80C188EB ports. These signals include **SCANLEDL**, **SCANPWR**, **RSENABLE**, **ENABLEL**, and **SOS** which support the scanner interface and **SRTS**, **SCTS**, and **TXDEN485** which control the RS–232 and RS–485 interfaces.

2.11 ROM Memory

As described in section 2.3.1, the RT1100 terminal has 512K bytes of masked ROM which contains the bootstrap loader and character generator tables. (For initial test and production units, the masked ROM may be replaced by a programmed EPROM device.) The ROM U5 is addressed by 19 bits of the 80C188EB address bus **A0–A18** and selected by the UCS chip select line **ROM** connected to the ROM CE input U5 pin 22. Data is gated to the processor data bus by **RD** which is connected to the ROM OE input U5 pin 24.

2.12 FLASH EPROM Memory

The TM1100 terminal has up to 256K bytes of FLASH EPROM memory which is a memory technology that is similar to the well known ultraviolet erasable EPROM except that erasure is accomplished electrically. Consequently, no unit disassembly, sockets, service handling or the like are necessary for program modification or updates. The FLASH EPROM is addressed by 18 bits of the 80C188EB address bus **A0–A17** and is selected by the GCS6 chip select line **FLASH** connected to the FLASH CE input U8 pin 30. Data is gated to the processor data bus by **RD** which is connected to the FLASH OE input U8 pin 32. Programming the FLASH U8 requires application of a 12 volt power supply **VPP** to the VPP input at pin 9 of U8. The TM1100 charge input is the source of the 12 volt supply which is switched by the H8/325 processor to control the **VPP** programming supply. The switch uses both sections of Q1 FMC3 consisting of a PNP and an NPN transistor with bias resistors controlled by the H8/325. When FLASH programming is en-

While not as power efficient as full static CMOS RAM, the pseudostatic RAM is a CMOS device with favorable data retention power consumption. The worst case standby retention current in the self–refresh mode is 200 μa. Power for memory data and real time clock retention in the ASIC is provided through a power backup system consisting of the main terminal battery and a "supercap" for retention when the main battery is removed. When the main battery is in place, the backup power supply RAMV+ is generated by a low power MAX667 voltage regulator REG2 whose output is directed through a diode CR5 to the RAMV+ bus. Resistors R69 309KΩ and R73 100KΩ set the output voltage of the regulator to +5 volts. It should be noted that the blocking diode CR5 does not contribute to error in the setting of RAMV+ since the output voltage is sensed after the diode. The MAX667 regulator REG2 has a voltage sense capability that detects that the output voltage has dropped out of regulation using its LBI (pin 3) and LBO (pin 7) pins connected through resistors R56 475KΩ, R66 3.9MΩ, R83 267KΩ and R57 100KΩ. R83 and R57 form a voltage reference, R66 provides switching hysteresis, and R56 is a pullup of the open drain output for logic interface to the ASIC for its VCC valid **VCC_VH** input. Backup power is provided by the supercap C29 0.3F when the main terminal battery is removed. Charging current to the supercap C29 is limited by the 100Ω resistor R58 so the regulator REG2 is able to generate the +5 volt RAMV+ voltage immediately. During standby operation, the delivered current is so low that virtually no voltage drop is seen through the 100Ω impedance to the backup load of the RAM and ASIC. Capacitors C25 10μF and C35 0.1μF provide supply bypassing for the RAMV+ supply. Resistor R67 17.4Ω and capacitor C36 1μF provide bypass filtering and isolation for the RAMV+ backup supply circuit.

It should be noted that since the power supply for the ASIC is the **RAMV+** supply, pullup derived voltages must be pulled up to this supply. Consequently, the pullups R16 100KΩ, R18 100KΩ and R23 100KΩ and reset circuit R41 100KΩ and capacitor C23 0.1μF are all connected to the **RAMV+** supply.

2.14 Display

The TM1100 display is a module using liquid crystal technology which includes a Hitachi 66108 controller/driver, an electroluminescent backlight panel, a circuit board and interconnection to the glass. The 66108 controller is a graphic mode device with internal pixel mapped memory, so character generation must be done externally. In the case of the TM1100, the character generation function is performed by the 80C188EB with character generation storage contained in the masked ROM as described in sections 2.3.1 and 3.2. The display drive configuration is as shown in Figure 2–2.

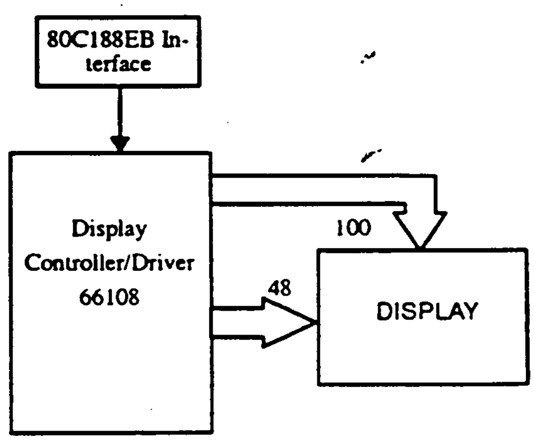


Figure 2–2
Display Driver Configuration

The display is physically arranged as 48 pixel rows x 100 pixel columns, which allows character or graphic information to be displayed. The most typical display mode will be the 5 x 7

switching threshold. The multiplexing waveforms are as shown in Figure 2–3.

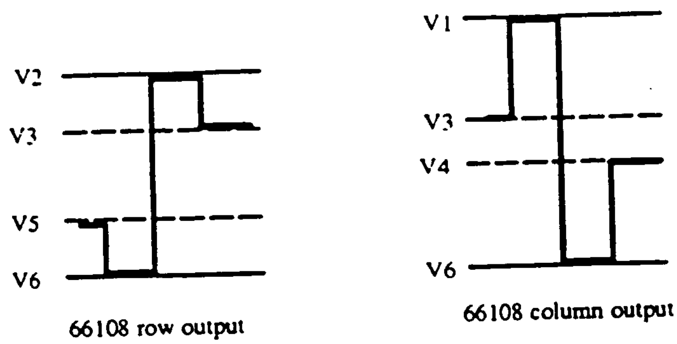


Figure 2–3
LCD Multiplexing Waveforms

The row and column multiplexing and driving circuits are completely contained in the display module. A further description of the LCD multiplexing technique may be found in the RT1000 Theory of Operation, Norand document 561–014–029.

2.15 Display Backlight

The TM1100 display module contains an integral electroluminescent backlight panel for operation in low light environments. Generation of the high voltage AC power supply required to energize the electroluminescent panel is accomplished on the TM1100 circuit board. The electroluminescent drive circuit consists of logic in the ASIC, external switching transistors Q7–A and Q7–B, a toroidal transformer T1, diode CR6 and optically isolated SCRs U12 and U13 with drive waveforms as shown in Figure 2–4. The drive method involves driving the transformer T1 via the ASIC signal QPH1 Q7–A at a 115 Khz rate for 8 cycles with SCR U13 turned on which causes the voltage at the panel EL (waveform 5) to ramp up to approximately 50 volts. SCR U12 is then turned on which causes the stored charge in the capacitive electroluminescent panel and capacitor C49 4700 pf. to flow through the transformer secondary. As the current builds up, reaches its peak and begins to decay, charge is delivered back to the electroluminescent panel in the reverse direction which causes the panel voltage **EL** to become negative. After this polarity reversal has been concluded, the ASIC signal **QPH2** causes 8 pulses at the 115 khz rate to be driven in the reverse direction through the transformer T1 via Q7–B which further drives the voltage EL to –50 volts. Waveforms 1 and 2 illustrate the pulsed drive voltages to transistors Q7–A and Q7–B. Waveforms 3 and 4 indicate the drive signals to SCR switches U13 and U12. Waveform 6 indicates the current required from the power supply **BATT+** and the filter capacitor C43 33 µF. to the center tap of the transformer T1, and waveform 7 indicates the current flow through the electroluminescent panel itself. The frequency of a complete cycle as illustrated from the time T1 to time T7 is 920 hz.

Control and timing of the signals shown is generated by the digital ASIC U4. Timing is provided by the 18.432 Mhz processor crystal which is divided down to develop the necessary frequencies. The frequency of the 8 pulses is 115 khz, with duty cycle modulation of the pulse width to allow modification of the output voltage and resulting panel brightness. The duty cycle of the drive pulses is adjustable by the processor in 16 – 2.5% steps from 20% tc 57.5%. The initial duty cycle after reset is 20%.

The optically isolated SCR switches are somewhat unique devices in that they switch on with a coincidence of the optical drive and gat current. To insure that the switch stays on dur ing the entire pulsing time, the optical drive is maintained for the whole time. The gate current for U13 is provided through resistor R65 22.1 kΩ and capacitor C34 1000 pf and for U1 through R63 22.1 kΩ and C28 1000 pf. The

to as many as 8 steps depending on which key is activated. Because the keyswitch is an electromechanical contact, there is associated switch bounce which causes the input signal to oscillate between its closed and open states for a period of a few milliseconds. This switch bounce is handled by repeatedly reading the column line inputs until the states have not changed for 30 msec., at which time the key input is received and processed. Note that the power–on key is brought out separately as a single pole/single throw switch for control of the power control latch. This key is identified to the scanning matrix by use of an isolation diode CR3 such that when the switch is pressed, the **COL0** line is pulled low with no **ROW** line driven by the H8/325, which can occur under no other condition.

The keyboard interfacing method described here is intended to be used with only a single key pressed at a time. If more than one key is pressed, it is possible that one of the keys will be received correctly, although some ambiguity may exist depending on which keys are pressed. In general, it is assumed that pressing multiple keys simultaneously is an improper operation, and an error may result.

As key input is detected by the H8/325 processor, the 80C188EB is alerted and the key codes are transferred to the 80C188EB application program in a manner similar to a typical personal computer.

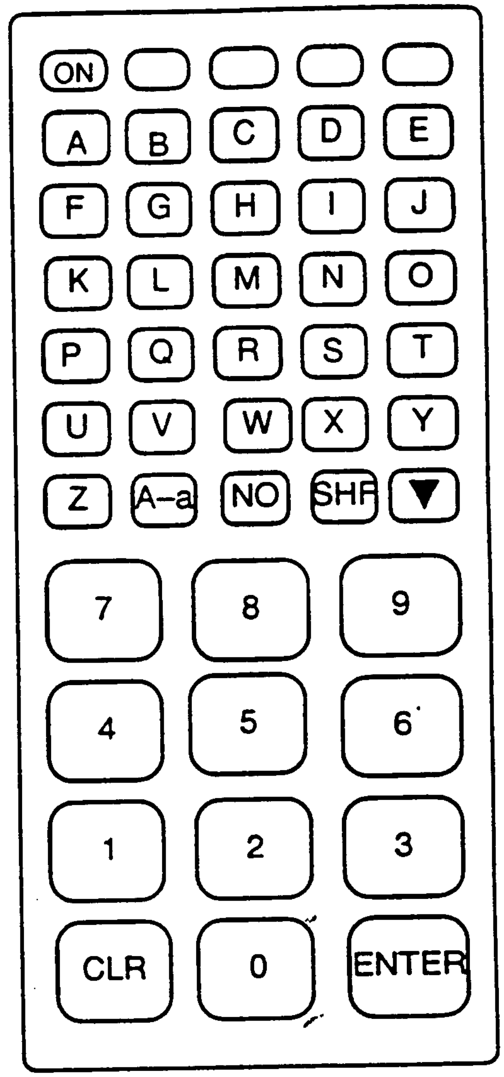


Figure 2–5 *Keyboard Layout*

2.17 Expansion Module Interface

The TM1100 terminal has the facility for a separately removeable module which may contain a variety of peripherals including radio transceivers, scanners, modems, automatic identification units or memory of several types. At the initial introduction of the TM1100, the expansion module will contain either a radio module or will be a blank unit utilizing only the basic terminal memory and peripherals.

2.17.1 Radio/Scanner Interface Signal Descriptions

2.17.1.1 BATT+ (P2–1)

BATT+V is the +7.2 volt positive battery terminal. This signal is unswitched, so the expansion module must be switched so that the off state current consumption is virtually zero. The power is switched by RADION and +5V.

2.17.1.2 RADION (P2–2)

RADION is the basic power control for the expansion module. When this signal is high, the expansion module is powered off.

2.17.1.3 PTT (P2–3)

PTT enables the expansion module transmitter when driven low.

2.17.1.4 RXDATA (P2–4)

RXDATA is the received data from the expansion module.

2.17.1.5 TXDATA (P2–5)

TXDATA is the transmitted data to the expansion module.

2.17.1.6 SP48_96 (P2–6)

SP48_96 is the data rate select to the expansion module. When low, the data rate is 4800 bps, and when high the data rate is 9600 bps.

2.17.1.7 +5V (P2–7)

+5V is the regulated +5 volt power from the terminal.

2.17.1.8 RX_AUDIO (P2–7)

RXAUDIO is a signal generated by the expansion module that is used only for test purposes and is not connected on the processor board. RXAUDIO is the raw received analog signal from the radio transceiver.

2.17.1.9 TXDC188 (P2–9)

TXDC188 is the serial async transmitted data line from the 80C188EB processor and may be used for high speed communication without delay through the H8/325 processor.

2.17.1.10 RXDC188 (P2–10)

RXDC188 is the serial async received data line from the 80C188EB processor and may be used for high speed communication without delay through the H8/325 processor.

2.17.1.11 TXF0 (P2–11)

TXF0 is a test signal from the H8/325 processor. When the expansion module is an RF transceiver, TXF0 is driven into the radio module to force the transmitter to output the unmodulated center frequency.

2.17.1.12 GND (P2–12)

Ground.

2.17.1.13 DATA (P3–1)

DATA is the signal from the integrated scanner corresponding to the widths of bars and spaces of the bar code being read.

SST system which is more complex than the resident H8/325 processor in the TM1100 is able to support. Consequently, the SST module has built-in facilities for the protocol requirements and a direct interface to the 80C188EB processor through the **RXDC188** and **TXDC188** signals. Power control is still handled by the H8/325 so that the 80C188EB is in its lowest power operating state until data must be handled for transmission or reception.

2.17.3 Integrated Scanner

Signals are included on the expansion module interface to support an integrated scanner of several types similar to the cable attached moving beam scanners. Several of the integrated scanner interface signals are identical to the cable attached scanner signals including **SOS**, **DATA** and **VSCAN+**. The **RSTRIG** and **RENABLE** signals are specifically received from the integrated scanner to determine when the operater has depressed its trigger switch and desires for that scanner to operate. A more detailed description of the scanner interface is included in section 3.9.

2.18 Scanner Interface

The external scanner interface consists of a "de facto" industry standard locking 9–pin "D" subminiature connector with interface circuits to the processor. Operation of a typical moving beam scanner is initiated by the operator depressing the trigger switch, which shorts the **TRIGGER** line (pulled up to +5V through 2.21kΩ resistor R50) to ground. This signal, like all of the lines connecting to the external connector, is passed through an ESD protection network consisting of a resistor and tranzorb. In the case of the **TRIG** line, the resistor is R51 2.21kΩ and the tranzorb is TZ2–B. The clamped signal is connected directly to an input port to the H8/325 processor. When **TRIG** is activated, the H8/325 processor responds by asserting **ENABLE** high to enable the scanner to operate. This is accomplished by driving the signal **ENABLEL** low which turns on transistor Q10 FMA8. The transistor emitter is tied to +5V, so the transistor collector voltage is switched to nearly +5V. The **ENABLE** output is routed through ESD protection consisting of TZ1–D and 392Ω R78 to the 9 pin connector.

As soon as **ENABLE** is received by the scanner, it will shortly begin outputting **SSOS** which is an approximately square wave indicating the area of the scanning field. The **SSOS** signal is pulled up through 2.21KΩ R47 and coupled through ESD protection network 2.2KΩ R48 and TZ1–C to the H8/325 processor. As soon as a bar coded label is placed in the scanning field, information is encoded on the **SDATA** output which is representative of the bar and space widths of the code. The **SDATA** signal is pulled up through 2.21KΩ R49 and is coupled through ESD protection network 2.21KΩ R45 and tranzorb TZ1–B to the H8/325 processor.

As soon as the H8/325 processor determines that the **TRIGGER** switch has been activated, it immediately alerts the 80C188EB processor which has high speed counters on board for high resolution signal capturing. Scan decoding is performed by the 80C188EB by converting the signal received on the **SDATA** line to digital counts that are proportional to the widths of the signal pulses, which of course are representative of the widths of the bars and spaces. Once all of the counts are captured, decoding of the encoded information proceeds. The TM1100 may contain decoding algorithms for any number of bar code types. Any or all of these algorithms may be enabled depending on configuration settings in the terminal. The decoding procedure attempts to decode the stored counts using all of the enabled algorithms until all possibilities have been exhausted. If none of the algorithms results in

constant is implemented by 1.2MΩ resistor R52 and .1µf capacitor C24. Power is turned on by momentarily depressing the power–on switch which causes the set input of the latch at pin 8 of CD4093 U11–C to go low quickly. The long time constant at the reset input of the latch at pin 6 of CD4093 U11–B causes the reset input to be held high for several seconds after the switch is depressed. Consequently, if the ON/OFF key is depressed for a time shorter than this time constant, the set input will prevail and set the latch output. If the ON/OFF key is depressed for a time longer than this time constant, both the set and reset input will be held low for the time that the key is depressed, but the set input will go high much sooner than the reset input, so the latch will be reset. The result of this configuration is that the unit will be powered off by pressing and holding the ON/OFF key for a time longer than the time constant of the reset input. This time is nominally around 3 seconds. The NAND gates used to implement the power control latch are Schmitt trigger input types to properly handle the very slowly changing inputs and prevent oscillation or mistriggering as the R–C voltages charge and discharge. The supply voltage for the CD4093 is created by the 15 volt MMBZ5245 zener diode Z2, limiting resistor 2.21KΩ R55 and 10µF capacitor C26 which prevents overvoltage from being applied to the CD4093 if the battery pack is removed while the unit is connected to a charger.

The output of the latch controls the TM1100 voltage regulator by driving the gate of a P–channel MOSFET Q5 ZVP3306 which switches the base current path for the regulator pass transistor Q6 XT2907A. The voltage regulator uses an LP2951 REG1 as the regulator controller with the external pass transistor. Since the quiescent current consumption of the LP2951 is quite low, it is possible to configure the external pass regulator such that the regulator is powered by the bias current for the pass transistor. Regulation is performed by controlling the base current of the external pass transistor through the output of the LP2951 to ground. The maximum base current is limited by tying the LP2951 output to ground through a 392Ω limiting resistor R59. The LP2951 has a built–in voltage reference and feedback ratio for +5V regulation which is implemented by connecting the SENSE input to the regulated output and connecting the +5VTAP to the FEEDBACK input. The +5VTAP is a tap in a voltage divider resistor circuit internal to the LP2951 that accurately sets the output voltage to +5V.

Power is turned off by resetting the power control latch which turns Q5 off. The bias current to the XT2907A pass transistor Q6 is switched off, and the 4.75KΩ back bias resistor R64 insures that Q6 doesn't leak any current. Power is switched off by the operator depressing the ON/OFF key momentarily which alerts the H8/325 processor that a shutdown sequence has been initiated. The H8/325 then signals the 80C188EB to prepare to shut down and then drives transistor switch Q3 FMG2 with the signal **PWRDN** to reset the power control latch. The H8/325 may also initiate a shutdown sequence when it senses that the battery voltage has discharged to its lower limit to prevent excessive discharge of the battery.

Filtering of the regulated output voltage for noise and stability considerations is provided by capacitors C37 100 pf and C32 33µf. Capacitor C30 100pf is required for stability of the regulator. Capacitor C31 1000 pf is a noise bypass capacitor.

2.20 Battery Charger

The NiCad batteries used in the TM1100 terminal are rechargeable batteries that require constant current charging. The basic charge circuit consists of transistor Q8 XT2907A, par-

DIN connector with the **ERXDA** and **ETXDA** signals shared by both.

The RS–232 signals are generated and received by a MAX242 U14 which contains a ±12 volt power supply circuit and high voltage drivers and receivers. The ±12 volt supply uses 0.1 µf capacitors C39, C401, C41 and C42 to generate those voltages from +5 volts using the charge pump technique. The MAX242 is placed in its shutdown mode by the **SHUTDN** signal from the H8/325 processor to conserve power when it is not being used. ESD protection of the RS–232 signals is provided by resistors R71, R88, R76 and R72 1KΩ and tranzorbs TZ3–A,B,C and D. **ECTSA** is tied through resistor R75 100KΩ for a default "off" condition.

The RS–485 interface consists of an LTC485 CMOS RS–485 transceiver integrated circuit which may be enabled when the MAX242 RS–232 driver is disabled. The driver enabling is done under the control of the H8/325 processor as part of the terminal configuration function. When the LTC485 is enabled, its receiver is turned on by the H8/325 driving the **REN485** signal low, and its transmitter is turned on similarly by driving the **TXDEN485** high. The outputs of the MAX–242 are turned off by driving its EN input through inverter connected comparator U7–B when the **REN485** signal is driven low. The outputs of the LTC485 are connected to the connector pins through pullup resistor 100KΩ R85 and series resistor 17.4Ω R86 and pulldown resistor 100KΩ R87 and series resistor 17.4Ω R77 to hold the proper default levels on the RS–485 lines while providing ESD protection. When the LTC485 drivers and receivers are off, the LTC485 device presents a high impedance to the multidrop bus. In addition to meeting the RS–485 multidrop requirements, this also allows sharing of the pins in the mini–DIN connector with the RS–232 **RXD** and **TXD** lines.

In the cases of both the RS–232 and RS–485 interfaces, the received and transmitted data is routed to the 80C188EB processor serial port 0 which allows direct interaction with the application program and communication structures typically required. In general, operation of the serial port will be a high current consumption mode, since it is necessary for the 80C188EB to be operating to support the communication function.

2.23 ASIC

As has been mentioned at several points, a significant portion of the functionality of the TM1100 is implemented in a digital ASIC. Figure 2–6 is an outline of the ASIC, showing pin locations and signal names. Table XX defines each signal name and describes the functin of each. The ASIC provides the processor clocks, real time clock, memory decoding, processor intercommunication, backlight drive and miscellaneous functions that otherwise would require a significant number of integrated circuit devices to implement.

The ASIC is primarily a bidirectional interface chip linking the 80C188 processor with the H8 processor. Logic within the ASIC controls data flow through the 8 bit bus. Also part of the ASIC are a 32 bit real time clock, backlight controller/driver circuit, an 11 bit address latch for the 80C188 processor, and two oscillators—one 32,768 Hz oscillator and one 18.432 MHz oscillator. The two oscillators provide timing signals for the ASIC, H8 processor, and backlight circuitry.

Refer to figure XX. The ASIC must always have power applied to maintain the real time clock (RTC). To reduce power consumption, power management logic is provided by the VCC_VH signal. When VCC_VH is at logic 0, the ASIC is in the low power consumption state. During this state, only the 32,768 Hz os-

cillator and RTC are powered. The 18.432 MHz oscillator is stopped and the following inputs are pulled to logic 0 through pull down resistors:

BKLITE	H8CSL	H8D (7:0)	WRL
DATA	AI16	AD (7:0)	AI18
H8WRL	C1_CSL	AI17	RFRENH
H8RDL	RDL	RMCSIL	ALEH

Table 2-8 *ASIC Pin Name Definitions and Descriptions*

PIN	NAME	DESCRIPTION
1 16 20 41 60	VCC	tbd
2 thru 4	AI16 thru AI18	Highest three bits of address data from the 80C188 processor
5 thru 7	A16 thru A18	Highest three bits of address data applied to te 80C188 address bus (latched by ALEH—pin-59)
8 13 21 33 40 61 80	GND	Ground
9	OSC16I	Input from crystal for 18.432 MHz oscillator circuit
10	OSC16O	Output to crystal for 18.432 MHz oscillator circuit
11	H8EXTL	Inverted clock signal, referenced to pin-13 (H8XTL)
12	H8XTL	Clock signal for H8 processor. Frequecy equals 9.216 MHz, or one-half the 18.432 MHz oscillator frequency
14	LED2	High source–current output for backlight power circuit (complimentry signal to LED1)
15	LED1	High source–current output for backlight power circuit (complimentry signal to LED2)
17	QPH1	Phase 1 drive signal for electroluminescent backlight transformer circuit (complimentry signal to QPH2).
18	QPH2	Phase 2 drive signal for electroluminescent backlight transformer circuit (complimentry signal to QPH1).
19	BKLITE	Command signal from H8 processor that activates display backlight (active high).

2.23.1 H8 Interface

The H8 processor sends data to the 80C188 data bus by first placing the data on the H8 bus and asserting H8WRL and H8CSL. This latches the H8 data and asserts the SLCHRDY output, telling the 80C188 processor that data is ready for transfer.

The H8 processor receives data from the 80C188 when SLBUSY is asserted, indicating new data is in the data latch. When SLBUSY is asserted, the H8 processor asserts H8RDL and H8CSL, placing the new data on the H8 bus and clearing SLBUSY.

2.23.2 80C188 Interface

The 80C188 processor controls most functions performed by the ASIC. It can transfer data to or from the H8 processor, controls the operation of the backlight circuitry, and reads the RTC 32 bit value.

To send data to the H8, the 80C188 performs a two step function. The first step is to load address 06 into the address latch in the ASIC. In step two the 80C188 places data onto the bus and asserts C1_CSL and WRL. This latches the 80C188 data and asserts the SLBUSY output, telling the H8 processor data is ready for transfer.

To receive data from the H8 processor, SLCHRDY must be asserted, indicating new data is present in the address latch. When SLCHRDY is asserted, the 80C188 asserts RDL and C1_CSL. This places the data in the address latch onto the 80C188 data bus and clears SLCHRDY.

The 80C188 interface is memory mapped based on the three least significant address bits. Once the addrss is latched and C1_CSL is asserted, a read or write operation can occur.

The memory map for the 80C188 processor is shown in Table 2–11.

Table 2–11 *80C188 Memory Map*

ADDRESS	OPERATION	FUNCTION
0	C188 read	Read byte0 of the RTC
1	C188 read	Read byte1 of the RTC
2	C188 read	Read byte2 of the RTC
3	C188 read	Read byte3 of the RTC
4	C188 write	Reset the RTC
5	C188 read	Read SLBUSY and SLCHRDY signals on data bus.
6	C188 read	Read latched H8 data and reset SLCHRDY signal.
6	C188 write	Latch C188 data bus and assert SLBUSY.
7	C188 read	Clear SLBUSY and SLCHRDY signals.

2.23.3 Psuedo–static RAM Control

The ASIC controls the read and refresh operations of the psuedo–static RAM using its VCC_VH, RDL, and RNCSIL inputs, and its RAMRDL and RMCSOL outputs. Control of the psuedo–static RAM is described in Table 2–12, by showing the logic state of the ASIC psuedo–static RAM control lines for each RAM function.

2.23.4 Backlight Control

ASIC control of the electroluminescent backlight is accomplished with the ASIC's QPH1 and QPH2 outputs. QPH1 and QPH2 drive drive two FETS in the backlight power circuitry (refer to paragraph 3.6 Backlight), which then excite primary winding of the EL transformer.

The LED1 and LED2 outputs of the ASIC trigger the LED inputs on two optically isolated

APPENDIX C:

RT/DT 1100 RADIO DATA TERMINAL SPECIFICATIONS

Compact, Pocket-sized Terminal Offers Scanning and Memory Capabilities Simply by Changing Modules

Radio Data Terminal

The RT/DT1100 Terminals offer more options in a light-weight, compact terminal that is one-third the size and half the weight of other terminals. The unique modular design allows the user to add capabilities simply by changing modules.

The base terminal can be purchased with your choice of modules to fit your specific needs. The integrated scanning version frees a user's hand for uninhibited key entry operation and for handling merchandise, while improving reliability.

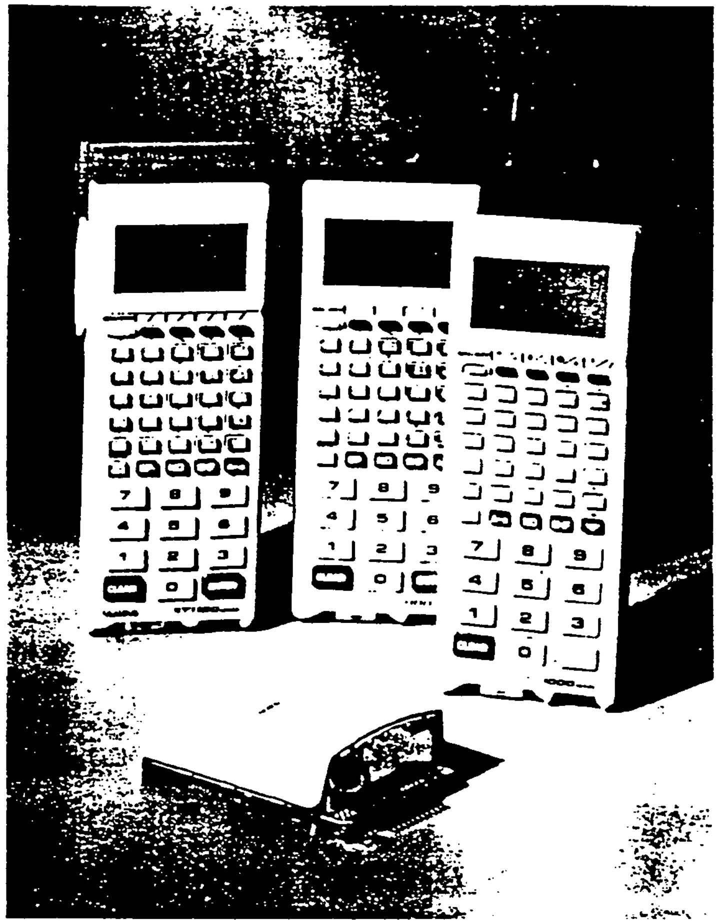
The RT/DT1100 incorporates an LCD backlit display for high visibility in dark environments. The display can be programmed in a 4, 6, 8, or 9 line by 12 or 16 character format. This provides the user with the display screen flexibility to accommodate various applications.

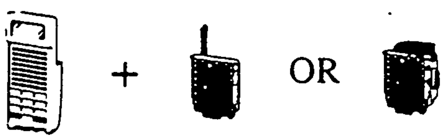
The RT/DT1100 has dual processors for faster terminal performance and enhanced system distributed processing capability. This feature provides the end user with a tool for maximizing productivity.

Terminal emulation for 3270, 5250, 7527, NORAND® Native Mode (Async), and VT220 is supported by the RT1100 system. These emulations enable easy communications with networks operating SNA, TCP/IP, DECnet, and Async protocols. This allows easy integration into your existing system and gives you the freedom to work directly with host data from remote areas of your facility. You can also develop your own applications in MS-DOS compatible languages (MS-DOS V5.0 optional), or in Microsoft C.

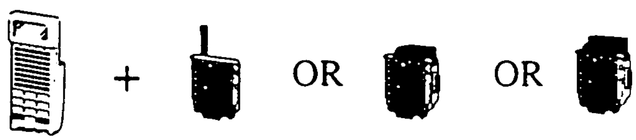
The RT/DT1100 will support printers and other RS232 and multidrop RS485 interface devices. This connectivity provides the expansion capabilities to meet your changing needs.

If you only need batch data terminal functionality now, start with the DT1100, then upgrade to RF when you're ready. This modular architecture allows you to adapt to the changing demands of your environment while preserving your investment.

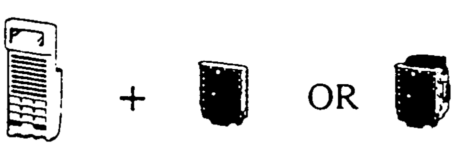




TM1000 Terminal Module — Standard UHF Radio Module — Integrated Scanner UHF Radio Module



TM1100 Terminal Module — Standard UHF Radio Module — Integrated Scanner UHF Radio Module — Integrated Scanner SST Radio Module



TM1100 Terminal Module — Standard Module — Integrated Scanner Module

FEATURES

- Flexible modular design provides added capabilities for less cost
- One-handed operation with integrated scanning options
- Terminal emulation for easy implementation
- MS-DOS compatible application environment
- Easy to install and service

NORAND DATA SYSTEMS

RT/DT1100 Radio Data Terminal

SPECIFICATIONS

...Communications Commission. The devices are not, and may not be, offered for sale or lease, or sold or leased until the approval of the FCC has been obtained.

PRODUCT FEATURES

Transceiver: Incorporates a 1 watt (UHF) frequency modulated (FM) radio transceiver controlled by the microprocessor. Type accepted per FCC Rules & Regulations, Parts 2 & 90, Private Land Mobile Radio Service

Liquid Crystal Display (LCD): 4, 6, 8, or 9 lines x 12 or 16 character with backlight and annunciators, plus full bit-mapped graphics capability

Keyboard: Elastomer 47-key alphanumeric

Annunciators: Fully programmable

Radio Module: Patented self-contained, interchangeable 1-channel radio module with built-in receiver self-test

Optional Modules: UHF or SST radio with CCD (up to 1" depth of field) or laser (0" to 30" depth of field) scanning

Radio Antenna: Screw-in antenna connects directly to the end of the radio module. Integrated scanning versions have an internal antenna

Processors: Two 16-bit microprocessors

ROM: 512 Masked plus 256K Flash

RAM: 512K Pseudo-static RAM

Terminal System Emulation: 3270, 5250, 7527, NORAND® Native Mode (Async), and VT220

Application Support: Microsoft "C" and "C" libraries: other languages with optional MS-DOS V5.0

Peripheral/Host Direct Connect Interface: 6-pin mini-DIN for RS232 and multi-drop RS485 interface devices

Drop Survival: Designed to withstand multiple 4-foot drops to concrete

Hand Strap: Incorporates a user replaceable, elastic hand strap to secure the terminal firmly in hand

Belt Attachment Point: Removable clip allows terminal to be fastened to the belt

Shielding: Conforms to FCC Part 15 for Class A computing devices

Audible Tone: Audible annunciator to alert operator of action

Scanner Interface: 9-pin D-subminiature connector for interface to 5-volt scanning peripherals with built-in scanning self-test

Electrostatic Discharge: Designed to withstand up to 20KV for Class C products

PHYSICAL DIMENSIONS

Size: 6.875" x 2.625" x 1.25" (LWD) (17.46cm x 6.68cm x 3.18cm)

Antenna Length: 2" (5.08cm)

Weight: 15.2 ounces (430.9g)

ENVIRONMENTAL CHARACTERISTICS

Operating Temperature: 32° to 122°F (-0° to 50°C)

Storage Temperature: -22° to 158°F (-30° to 70°C)

Recharging Temperature: 41° to 104°F (5° to 40°C)

Humidity: 10 to 90% noncondensing

Altitude: To 10,000 feet (3,048 meters) above sea level

INTERNAL POWER SOURCE

Battery Cells: Standard rechargeable nickel-cadmium battery pack

Voltage: 7.2 VDC (nominal)

Operating Time Between Charges: 8 hours typical, based on customer usage of 8 scans/transmissions per minute

RT1000 BATTERY PACK CHARACTERISTICS

Normal Recharge: 12 hours in terminal; 3 - 4 hours external

Pack Life: At least 500 discharge/charge cycles

Low Battery Indicator: Visual annunciator indicating low battery is displayed on the LCD

Charging Sources: AC adapter-type single terminal chargers and multi-battery pack chargers available

RADIO CHARACTERISTICS

Radiated Power: 1 watt (maximum)

Frequency Range: 450 to 470 MHz

RF Data Rate: 4800 baud

BAR CODE SCANNING SUPPORT

Bar Code Scanners Supported: CCD (5V), Visible Laser Diode (5V), Pen Wand (5V)

Bar Code Symbologies Supported: UPC, UPC with add-ons, EAN, EAN with add-ons, Code 39, Interleaved 2 of 5, Code 128, Plessey, Code 93, Codabar, ABC Codabar, Straight 2 of 5, Encoded Code 39, Extended Code 39

NORAND® DATA SYSTEMS

The goal of Norand is 100% customer satisfaction. Customer Satisfaction Hot Line: 1-800-221-9236

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1-800-633-6157 toll free
FAX: 416-477-2242

This document contains preliminary product specifications. In a continuing effort to improve our products Norand Corporation reserves the right to change specifications and features without prior notice.

APPENDIX D:

A PORTION OF THE PROTOCOL STACK UTILIZED BY THE TM 1000

```
#define _DEBUG
/* *******************          ************************          ************ */
/*                                                                              */
/*      ss_brid.c        rtl140/5940 sst bridge layer                           */
/*      Phillip Miller                                                          */
/*      version 24       7/1/94                                                 */
/*                       post reset_error on tx_done                            */
/*      version 23       6/28/93                                                */
/*                       delete unnessary reset_error                           */
/*      version 22       6/8/93                                                 */
/*                       attach backoff only on detach                          */
/*      version 21       6/4/93                                                 */
/*                       post netword error in missing hello                    */
/*      version 20       5/25/93                                                */
/*                       do not rarp on base cost=0xffff                        */
/*      version 19       5/19/93                                                */
/*                       fix detach packet response                             */
/*      version 18       5/10/93                                                */
/*                       have h8 monitor bases                                  */
/*      version 17       5/6/93                                                 */
/*                       fix radio strength selection                           */
/*      version 16       5/5/93                                                 */
/*                       fix attach timeout sw                                  */
/*      version 15       3/19/93                                                */
/*                       lint version of version 14/msc ver 7                   */
/*      version 14       3/11/93                                                */
/*                       set high order bit on NETWORK_RESET                    */
/*      version 13       3/5/93                                                 */
/*                       move power management from hello to attach             */
/*                       delete hello timers                                    */
/*                       do not send attach to chan. acq err.                   */
/*      version 12       3/3/93 fix TX DONE problems                            */
/*      version 11       2/25/93 fix cost=0xffff logic                          */
/*      version 10       2/18/93 require attach response                        */
/*      version 9        2/16/93 fix radio strength selection                   */
/*      version 8        2/12/93 fix version.base_adr                           */
/*                               remove self test 3                             */
/*      version 7        1/28/93 change error handler                           */
/*      version 6        1/15/93 remove test code                               */
/*      version 5        1/14/93 fix tx_done                                    */
/*                               change init parms                              */
/*                               check for cost=0xffff in hello                 */
/*      version 4        1/11/93 check interprocessor data check                */
/*      version 3        12/03/92 reset attach timer when data send             */
/*      version 2        11/13/92 fix self test                                 */
/*      Version 1        11/5/92 version control begins                         */
/* ************************************************************************** */
#define VERSION                                   24
#define BH_ROM_CODE_VERSION                       50
#define SPREAD_CODE                               0
#include                "bufpool.h"
#include                "ss_timer.h"
#include                "ss_brid.h"
#include                "errcodes.h"
#include                "brgerr.h"
#include                "llcbrg.h"
#include                "sst_ver.h"
#include                "say.h"
#define                 RSSI_72DB_MARK            11
#define                 RSSI_74DB_MARK            12
```

```
define                  1.   _76DB_MARK            13
define                  RS5I_78DB_MARK             14
define                  RSSI_80DB_MARK             15
* ************************************************************** */
nt                      memcmp();
roid *                  memcpy();
insigned int                      strlen();
:har *                  strcpy();
roid *                  memset();
/* ************************************************************** */
static void             disable_mac();
static void             load_code();
static void             state_detach();
static void             enable_mac();
static void             send_hello();
static void             send_inquire();
static void             write_base_adr();
static void             sort_bases();
static void             write_terminal_adr();
static void             send_attach();
static void             send_rarp();
static int              find_rarp_optional_parm();
static void             post_llc();
static int              try_next_base();
static void             ck_for_out_data();
static void             process_attach_data();
static void             process_attach_timer_request();
static void             process_attach_write_request();
static void             process_attach_data_hello();
static void             process_attach_data_attach();
static void             process_attach_data_arp();
static void             process_attach_data_detach();
static void             wrt_int_buf();
extern int              _radio_write(unsigned char *,int);
static void             send_arp();
static void             send_data();
static void             write_lan_adr();
extern int              _radio_read();
static int              rd_long_id();
static int              rd_version();
extern void             _radio_ss();
extern void             _radio_ss_timer_init();
extern void             _radio_ss_update_timers();
static void             process_bridge();
static void             process_attach_data_data();
static void             set_power_management();
extern void             llc_evt_handler(T_EVENT _far *);
extern int              _sst_h8_code_load();
static void             small_delay();
static unsigned char    get_strength(unsigned char s);
/* ************************************************************** */


#define DATA                      0
#define TIMER                     1
#define WRITE_RESPONSE            2
#define ATTACH_TIMER              3
```

```
/* timeout const  all t[illegible]re in .01 seconds */
#define HELLO_TIMEOUT_1                    60
#define HELLO_TIMEOUT_2                    200
#define RARP_TIMEOUT                       300
#define ERROR_OFF_TIME                     300
#define ATTACH_TIMEOUT                     48000
#define ATTACH_SHORT_TIMEOUT               1000
#define ATTACH_BACKOFF_TIMEOUT             800
#define ARP_TIMEOUT                        500

/* retry const */
#define ARP_TRIES                          5
#define HELLO_TRIES                        3
#define RARP_TRIES                         5

#define MAC_DEST_ADDR                      1
#define MAC_SOURCE_ADDR                    MAC_DEST_ADDR+2
#define RADIO_STRENGTH                     MAC_SOURCE_ADDR+2
#define BRIDGE_CONTROL                     RADIO_STRENGTH+1
#define BRIDGE_DEST_ADDR                   BRIDGE_CONTROL+2
#define BRIDGE_SOURCE_ADDR                 BRIDGE_DEST_ADDR+2
#define BRIDGE_PACKET_PARMS                BRIDGE_SOURCE_ADDR+2
#define BRIDGE_COST                        BRIDGE_PACKET_PARMS
#define BRIDGE_SEED_PRIORITY               BRIDGE_COST+2
#define RARP_NETWORK_ADR                   BRIDGE_PACKET_PARMS+1
#define ARP_NETWORK_ADR                    BRIDGE_PACKET_PARMS+1
#define BRIDGE_HELLO_OPTIONAL_FIELD        BRIDGE_PACKET_PARMS+6
#define BRIDGE_HELLO_ROOT_SEQ_NO           BRIDGE_PACKET_PARMS+5

static T_TIMER            bridge_timer;
static T_TIMER            attach_timer;
static T_TIMER            attach_backoff_timer;

static unsigned int       data_in_len;
static unsigned char      first_time_sw=0;

struct BASE_INFO
{
        unsigned char     strength;
        unsigned char     base_cost[2];
        unsigned char     radio_strength;
        unsigned char     base_priority;
        unsigned char     fil;
        unsigned int      base_short_adr;
};
static struct BASE_INFO bases[32];
static int                base_ptr;
static int                attach_timeout_type_sw;
static int                alias_len;
static char               alias_name[32];
static unsigned char      data_buf[1200];
static unsigned char      bridge_state=DETACH;
static unsigned char      terminal_long_id[6];
static unsigned int       terminal_short_adr;
static int                retry_cnt;
static int                arp_len;
static int                root_seq_number;
static unsigned int       root_id_len=0;
static unsigned char      root_id[32];
static unsigned char      attach_request_sw;
```

```
static unsigned char     ·e_request_sw=0;
static unsigned char     l_ _k_status_sw=LINK_DISABLED;
static unsigned char     inquire_sw=0;
static T_EVENT   _far    *tx_pending;
static SST_VERSION_CONTROL        sst_version;
static unsigned char     temp_out_buf[100];
static unsigned char     temp_in_buf[100];
static unsigned int      hello_reason_code;
static unsigned int      current_base=0;
static unsigned int      next_base;
static unsigned char     current_cost[2];
static unsigned char     next_cost[2];
static unsigned char     current_strength;
static unsigned char     next_strength;
static unsigned char     next_base_valid=0;
static char              rssi_valid=0;
static unsigned char     spread_code;
static unsigned char     rssi_tab[40];

/* ****************************************************************** */
static void state_detach()
{
        disable_mac();
}
/* ****************************************************************** */
/* ****************************************************************** */
static void start_acquire_bases(int send_hello_sw)
{
        _radio_ss_timer_stop(&bridge_timer);
        _radio_ss_timer_stop(&attach_timer);
        retry_cnt=0;
        sst_version.base_short_addr=0;
        enable_mac();
        if(send_hello_sw)
        {
                send_hello();
        }
        else
        {
                bridge_timer.interval=HELLO_TIMEOUT_2;
                bridge_timer.periodic=0;
                bridge_timer.task_adr=0;
                say("BTS hw-1\n");
                _radio_ss_timer_start(&bridge_timer);
                bridge_state=DETACH_WAITING_FOR_HELLO;
                base_ptr=0;
        }
}
/* ****************************************************************** */
static void state_detach_hello_write()
{
        bridge_timer.interval=HELLO_TIMEOUT_1;
        bridge_timer.periodic=0;
        bridge_timer.task_adr=0;
        say("BTS hw\n");
        _radio_ss_timer_start(&bridge_timer);
        bridge_state=DETACH_WAITING_FOR_HELLO;
        base_ptr=0;
}
/* ****************************************************************** */
```

```
tatic void state_detach_    ting_for_hello(type)
      int     type;

      unsigned int    i;
      int             j;

      if(type==DATA)
      {
              if(data_in_len < 14)return;

              if(base_ptr > 31)return;

              if((data_buf[BRIDGE_CONTROL] & 0x17) != 0x12)
                      return;                  /* return if not hello response

              i=data_buf[MAC_SOURCE_ADDR];
              i <<= 8;
              i |= (data_buf[MAC_SOURCE_ADDR+1] & 0x00ff);

              for(j=0;j<base_ptr;j++)
              {
                      if(i==bases[j].base_short_adr)return;
              }

              bases[base_ptr].strength=get_strength(data_buf[RADIO_STRENGTH]);
              bases[base_ptr].radio_strength=(unsigned char)(unsigned int)(256
              bases[base_ptr].base_short_adr=i;;
              bases[base_ptr].base_cost[0]=data_buf[BRIDGE_COST];
              bases[base_ptr].base_cost[1] = data_buf[BRIDGE_COST+1];
              if(bases[base_ptr].base_cost[0] == 0xff)return;
              bases[base_ptr].base_priority=data_buf[BRIDGE_SEED_PRIORITY] &
              bases[base_ptr].fil=0;
              base_ptr++;
              return;
      }
      if(type==TIMER)
      {
              if(base_ptr==0)
              {
                      if(retry_cnt < HELLO_TRIES)
                      {
                              _radio_ss_timer_stop(&bridge_timer);
                              retry_cnt++;
                              bridge_timer.interval=HELLO_TIMEOUT_2;
                              bridge_timer.periodic=0;
                              bridge_timer.task_adr=0;
                              say("BTS hw 1\n");
                              _radio_ss_timer_start(&bridge_timer);
                              bridge_state=DETACH_WAITING_FOR_HELLO;
                              base_ptr=0;
                              return;
                      }
                      retry_cnt=0;
                      disable_mac();
                      bridge_state=DETACH_BACKOFF;
                      bridge_timer.interval=ERROR_OFF_TIME;
                      say("BTS backoff\n");
                      _radio_ss_timer_start(&bridge_timer);
                      if(write_request_sw && (link_status_sw==LINK_ENABLED))
                      {
```

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```
                        evt_set_group(tx_pen   j,BRG_POST);
                        evt_set_type(tx_pendi..j,TX_DONE);
                        evt_set_error(tx_pending,BRG_ERR_MAC);
                        write_request_sw=0;
                        say("TX DONE err-mac 1\n");
                        llc_evt_handler(tx_pending);
                }
                return;
        }
        sort_bases();
        say("Number of bases=");
        sayword(base_ptr);
        say("\n");
        if(rssi_valid)
        {
                say("72db=");
                sayword(rssi_tab[RSSI_72DB_MARK]);
                say(",76db=");
                sayword(rssi_tab[RSSI_76DB_MARK]);
                say(",80db=");
                sayword(rssi_tab[RSSI_80DB_MARK]);
                say("\n");
                for(j=0;j<base_ptr;j++)
                {
                        sayhex((unsigned char *)(&bases[j]),sizeof(struc
                        say("\n");
                }
        }
        else
        {
                say("rssi table invalid\n");
        }
        current_base=bases[0].base_short_adr;
        current_cost[0]=bases[0].base_cost[0];
        current_cost[1]=bases[0].base_cost[1];
        current_strength=256-bases[0].radio_strength;
        retry_cnt=0;
        if(link_status_sw != LINK_DISABLED)
        {
                write_terminal_adr(terminal_short_adr);
                send_attach();
                return;

        }
        else
        {
                send_rarp();
                return;
        }
    }
}
/* ***************************************************************** */
static unsigned char get_strength(unsigned char s)
{
        if(rssi_valid==0)return(0);
        if(s >= rssi_tab[RSSI_72DB_MARK])return(0);
        if(s >= rssi_tab[RSSI_76DB_MARK])return(1);
        if(s >= rssi_tab[RSSI_80DB_MARK])return(2);
        return(3);
}
```

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```
/* ******************************************************************* */
static void state_detach_backoff(type)
        int     type;
{
        if(type==TIMER)
        {
                hello_reason_code |= HELLO_REASON_DETACH_BACKOFF;
                start_acquire_bases(1);         /* send hello */
        }
}
/* ******************************************************************* */
static void state_detach_waiting_for_rarp(type)
        int     type;
{
        unsigned int    i;
        int             j;

        if(type==DATA)
        {
                if(data_in_len < 14)return;

                if((data_buf[BRIDGE_CONTROL] & 0x17) != 0x16)
                        return;                 /* return if not rarp response *

                for(j=0;;)
                {
                        j=find_rarp_optional_parm(j);
                        if(j<0)return;
                        if((data_buf[j] & 0x7f)!=0x02)continue;
                        j=memcmp((unsigned char _far *)&data_buf[j+2],(unsigned
                        if(j)return;
                        _radio_ss_timer_stop(&bridge_timer);
                        i = data_buf[RARP_NETWORK_ADR] << 8;
                        i |= data_buf[RARP_NETWORK_ADR+1];
                        if(i==0xffff)
                        {
                                retry_cnt=0;
                                disable_mac();
                                bridge_state=DETACH_BACKOFF;
                                bridge_timer.interval=ERROR_OFF_TIME;
                                say("BTS backoff 1\n");
                                _radio_ss_timer_start(&bridge_timer);
                                if(write_request_sw && (link_status_sw==LINK_ENA
                                {
                                        evt_set_group(tx_pending,BRG_POST);
                                        evt_set_type(tx_pending,TX_DONE);
                                        evt_set_error(tx_pending,BRG_ERR_MAC);
                                        write_request_sw=0;
                                        say("tx done err-mac 2\n");
                                        llc_evt_handler(tx_pending);
                                }
                                else
                                {
                                        post_llc(BRG_ERR_AR_NO_ID);
                                }
                                return;
                        }
                        terminal_short_adr=i;
                        sst_version.term_short_addr=i;
                        write_terminal_adr(i);
```

```
                        _attach();
                        urn;
                }
        }
        if(type==TIMER)
        {
                retry_cnt++;
                if(retry_cnt > RARP_TRIES)
                {
                        retry_cnt=0;
                        if(try_next_base())
                        {
                                hello_reason_code|=HELLO_REASON_RARP_FAILURE;
                                start_acquire_bases(0);
                                return;
                        }
                }
                send_rarp();
        }
}
/* ****************************************************************** */
static void state_detach_waiting_for_attach(type)
        int     type;
{
        T_EVENT _far    *evt;

        if(type==DATA)
        {
                if(link_status_sw==LINK_DISABLED)
                {
                        return;
                }
                sst_version.base_short_addr=current_base;
                process_attach_data();
                return;
        }
        if(type==WRITE_RESPONSE)
        {
                sst_version.base_short_addr=current_base;
                attach_request_sw=0;
                if(data_buf[1]==0)
                {
                        set_power_management(0);
                        attach_timeout_type_sw=1;
                        say("HTS attw\n");
                        attach_timer.interval=ATTACH_SHORT_TIMEOUT;
                        say("ATS attw\n");
                        _radio_ss_timer_start(&attach_timer);
                        bridge_state=ATTACH;
                        if(link_status_sw==LINK_DISABLED)
                        {
                                link_status_sw=LINK_ENABLED;
                                attach_request_sw=0;
                                write_request_sw=0;
                                evt=event_get();
                                if(evt==0)
                                {
                                        say("unable to get event pt1\n");
                                        link_status_sw=LINK_DISABLED;
                                        return;;
```

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```
                        }
                        evt_set_group(evt,BR\ _.OST);
                        evt_set_type(evt,START);
                        say("BRIDGE_START\n");
                        llc_evt_handler(evt);
                }
                ck_for_out_data();
                return;
        }
        if(try_next_base())
        {
                hello_reason_code|=HELLO_REASON_ATTACH_WRITE_ERROR;
                start_acquire_bases(1);
                return;
        }
        send_attach();
    }
}
/* ************************************************************** */
/* ************************************************************** */
static void state_attach(type)
        int     type;
{
        switch(type)
        {
                case DATA:
                                process_attach_data();
                                break;
                case TIMER:
                                process_attach_timer_request();
                                break;
                case WRITE_RESPONSE:
                                process_attach_write_request();
                                break;
                case ATTACH_TIMER:
                                if(attach_request_sw==0)
                                {
                                        if(attach_timeout_type_sw)
                                        {
                                                attach_request_sw =2;
                                                hello_reason_code |= HELLO_REASO
                                        }
                                        else
                                                attach_request_sw =1;
                                }
                                break;
                default:
                                break;
        }
        ck_for_out_data();
}
/* ************************************************************** */
static void process_attach_data()
{
        switch(data_buf[BRIDGE_CONTROL] & 0x07)
        {
                case 0:         /* data packet */
                        process_attach_data_data();
                        break;
                case 1:
```

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```
                        break;
                case 2:         /* hello packet */
                        if(bridge_state != ATTACH)break;
                        process_attach_data_hello();
                        break;
                case 3:         /* attach packet */
                        process_attach_data_attach();
                        break;
                case 4:         /* detach packet */
                        if(bridge_state != ATTACH)break;
                        process_attach_data_detach();
                        break;
                case 5:         /* arp packet */
                        if(bridge_state != ATTACH)break;
                        process_attach_data_arp();
                        break;
                case 6:         /* rarp packet */
                        break;
                case 7:
                        break;
                default:
                        break;
        }
}
/* ***************************************************************** */
static void process_attach_data_data()
{
        T_EVENT _far            *evt;
        T_PACKET _far           *pkt;
        unsigned int            j;
        unsigned char           type;
        unsigned char           size;
        unsigned int            len;
        unsigned int            adr;


        len=data_in_len-1;
        j=len;
        if(j > 25)j=25;
        j=data_buf[BRIDGE_CONTROL+1];
        j >>= 3;
        j &= 0x07;              /* j= data link type */
        if(j !=1)       /* return if not llc */
        {
                return;
        }
        if(link_status_sw==LINK_DISABLED)return;
        j=BRIDGE_PACKET_PARMS;
        if(data_buf[BRIDGE_CONTROL+1] & 0x80)   /* optional parms */
        {
                for(;;)
                {
                        type=data_buf[j++];
                        size=data_buf[j++];
                        j += size;
                        if(type & 0x80)break;
                        if(j > data_in_len)
                        {
                                return;
                        }
```

```
                }
        }
        evt=evt_pkt_buf_mac_get(1000);
        if(evt == 0)
        {
                return;
        }
        pkt=evt_pkt_ptr(evt);
        (void)pkt_mac_copy_to(pkt,(char _far *)&data_buf[1],len);
        (void)pkt_mac_del_hdr(pkt,BRIDGE_CONTROL-MAC_DEST_ADDR);
        j -= BRIDGE_CONTROL;
        (void)pkt_brg_del_hdr(pkt,j);
        if(data_buf[BRIDGE_CONTROL] & 0x10)
        {
                evt_set_group(evt,BRG_POST);
                evt_set_type(evt,ERROR);
                evt_set_error(evt,BRG_ERR_UNABLE_TO_SEND);
                say("unable to send\n");
                llc_evt_handler(evt);
        }
        else
        {
                adr=data_buf[BRIDGE_SOURCE_ADDR]<<8;
                adr|=data_buf[BRIDGE_SOURCE_ADDR+1];
                evt_set_group(evt,BRG_POST);
                pkt_set_addr(pkt,adr);
                evt_set_type(evt,RX_DONE);
                say("RX DONE\n");
                llc_evt_handler(evt);
        }
}
/* ****************************************************************** */
static void process_attach_data_detach()
{
        unsigned int    j;
        unsigned int    i;
        unsigned int    k;
        unsigned int    l;
        unsigned int    m;

        if(_radio_ss_timer_running(&attach_backoff_timer))return;
        if((data_buf[BRIDGE_CONTROL] & 0x07) != 0x04)
                return;         /* return if not detach req/response */
        if(data_buf[BRIDGE_CONTROL+1] & 0x80)
                return;         /* return no optional parms */
        j=BRIDGE_PACKET_PARMS;
        for(;;)
        {
                i=data_buf[j];
                switch(i & 0x7f)
                {
                        case 0x04:                      /* detached list */
                                        j++;
                                        k=data_buf[j];
                                        if(k & 1)return;
                                        j++;
                                        k >>= 1;
                                        for(l=0;l<k;l++)
                                        {
                                                m=data_buf[j++];
```

```
                                        m <<   ;
                                        m |= (data_buf[j++] & 0x00ff);
                                        if(m==terminal_short_adr)
                                        {
                                                if(attach_request_sw==0)
                                                {
                                                        attach_request_s
                                                        _radio_ss_timer_
                                                }
                                        }
                                }
                                break;
                default:
                                j++;
                                j +=data_buf[j];
                                j++;
                                break;
                }
                if(i & 0x80)break;
                if(j > data_in_len)return;
        }
}
/* ************************************************************ */
static void process_attach_data_hello()
{
        unsigned int    j;
        unsigned int    i;
        unsigned int    k;
        unsigned int    l;
        unsigned int    m;
        unsigned int    base_adr;

        if((data_buf[BRIDGE_CONTROL] & 0x17) != 0x12)
                return; /* return if not attach response */
        base_adr=data_buf[MAC_SOURCE_ADDR];
        base_adr <<= 8;
        base_adr |= (data_buf[MAC_SOURCE_ADDR+1] & 0x00ff);
        base_adr &= 0x7fff;
        if((data_buf[BRIDGE_COST] == 0xff) && (data_buf[BRIDGE_COST+1] == 0xff)
        {
                if(base_adr ==  current_base)
                {
                        if(attach_request_sw != 0xff)attach_request_sw=2;
                        hello_reason_code |= HELLO_REASON_COST_FFFF;
                }
                return;
        }
        if(!(data_buf[BRIDGE_CONTROL+1] & 0x80))
                return; /* return no optional parms */
        if(root_seq_number < 0)
        {
                root_seq_number=data_buf[BRIDGE_HELLO_ROOT_SEQ_NO];
        }
        else
        {
                if(root_seq_number !=data_buf[BRIDGE_HELLO_ROOT_SEQ_NO])
                {
                        root_seq_number=data_buf[BRIDGE_HELLO_ROOT_SEQ_NO];
                        hello_reason_code |= HELLO_REASON_SEQ_NUMBER;
                        root_id_len=0;
```

```
root_seq_number=-1;
link_status_sw=LINK_DISABL
ay("Root seq changed\n");
if(write_request_sw)
{
        evt_set_group(tx_pending,BRG_POST);
        evt_set_type(tx_pending,ERROR);
        evt_set_error(tx_pending,BRG_ERR_NET_RESET);
        llc_evt_handler(tx_pending);
}
else
{
        post_llc(BRG_ERR_NET_RESET);
}
return;
        }
}
j=BRIDGE_HELLO_OPTIONAL_FIELD;
for(;;)
{
        i=data_buf[j];
        switch(i & 0x7f)
        {
                case 0x04:
                                        /* detached list */
                        j++;
                        k=data_buf[j];
                        j++;
                        k >>= 1;
                        for(l=0;l<k;l++)
                        {
                                m=data_buf[j++];
                                m <<= 8;
                                m |= (data_buf[j++] & 0x00ff);
                                if(_radio_ss_timer_running(&atta
                                {
                                        if(m==terminal_short_adr
                                        {
                                                if(attach_reques
                                                {
                                                        _radio
                                                        attach_
                                                }
                                                break;
                                        }
                                }
                        }
                        break;
                case 0x05:
                                        /* pending list */
                        j++;
                        k=data_buf[j];
                        j++;
                        k >>= 1;
                        for(l=0;l<k;l++)
                        {
                                m=data_buf[j++];
                                m <<= 8;
                                m |= (data_buf[j++] & 0x00ff);
                                if(m==terminal_short_adr)
                                {
                                        if(inquire_sw==0)
```

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```
                                        {
                                                if(base_adr ==
                                                {
                                                        if(inqui

                                                }
                                        }
                                        break;
                                }
                        }
                        break;
        case 0x0a:                      /* root long id */
        case 0x0b:                      /* root alais */
                        j++;
                        k=data_buf[j];
                        if(root_id_len==0)
                        {
                                if(k > 20)break;
                                root_id_len=k;
                                j++;
                                memcpy((unsigned char _far *)roc
                                j += k;
                                break;
                        }
                        if(k != root_id_len)
                        {
                                hello_reason_code |= HELLO_REASO
                                root_id_len=0;
                                root_seq_number=-1;
                                link_status_sw=LINK_DISABLED;
                                say("Root id len not equal\n");
                                if(write_request_sw)
                                {
                                        evt_set_group(tx_pending
                                        evt_set_type(tx_pending,
                                        evt_set_error(tx_pending
                                        llc_evt_handler(tx_pendi
                                        }
                                else
                                {
                                        post_llc(BRG_ERR_NET_RES
                                }
                                return;
                        }
                        j++;
                        for(l=0;l<k;l++)
                        {
                                if(root_id[l] != data_buf[j++])
                                {
                                        hello_reason_code |= HEL
                                        root_id_len=0;
                                        root_seq_number=-1;
                                        link_status_sw=LINK_DISA
                                        say("Root id changedd\n"
                                        if(write_request_sw)
                                        {
                                                evt_set_group(tx
                                                evt_set_type(tx_
                                                evt_set_error(tx
                                                llc_evt_handler(
```

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```
                                                }
                                                else
                                                {
                                                        post_llc(BRG_ERR
                                                }
                                                return;
                                        }
                                }
                                break;
                default:
                                j++;
                                j +=data_buf[j];
                                j++;
                                break;
                }
                if(i & 0x80)break;
                if(j > data_in_len)return;
        }
        set_power_management(1);
}
/* ****************************************************************** */
static void process_attach_data_attach()
{
        if((data_buf[BRIDGE_CONTROL] & 0x17) != 0x13)
                return;         /* return if not attach response */

        _radio_ss_timer_stop(&attach_timer);
        attach_timer.interval=ATTACH_TIMEOUT;
        say("ATS da\n");
        _radio_ss_timer_start(&attach_timer);
        attach_timeout_type_sw=0;

        if(!(data_buf[BRIDGE_CONTROL+1] & 0x04))
                return;         /* return if not ATTI */
        post_llc(BRG_ERR_ATTI);
}
/******************************************************************** */
static void process_attach_data_arp()
{
        unsigned int    i;
        char _far                       *arp_adr;
        T_BRG_LLC_FD _far               *ptr;

        ptr=(T_BRG_LLC_FD _far *)tx_pending->info;
        arp_adr=ptr->alias;

        if(write_request_sw != 3)return;
        if(data_in_len < 14)return;

        if((data_buf[BRIDGE_CONTROL] & 0x17) != 0x15)
                return;                 /* return if not arp response */

        if(memcmp((unsigned char _far *)&data_buf[ARP_NETWORK_ADR+7],(unsigned c
        _radio_ss_timer_stop(&bridge_timer);
        i = data_buf[ARP_NETWORK_ADR] << 8;
        i |= data_buf[ARP_NETWORK_ADR+1];
        if(i==0xffff)
        {
                evt_set_group(tx_pending,BRG_POST);
                evt_set_type(tx_pending,TX_DONE);
```

```
            evt_set_[illegible]or(tx_pending,BRG_ERR_AR[illegible]T_FOUND);
            write_re[illegible]st_sw=0;
            say("TX DONE AR_NOT_FOUND\n");
            llc_evt_handler(tx_pending);
            return;
        }
        ptr->address=i;
        write_request_sw=1;
        ck_for_out_data();

}
/* ************************************************************** */
static void process_attach_write_request()
{
        if(link_status_sw==LINK_DISABLED)
        {
                inquire_sw=0;
                write_request_sw=0;
                start_acquire_bases(1);         /* send hello */
                return;
        }
        if(inquire_sw==2)
        {
                inquire_sw=0;
                if(data_buf[1]==0)      /* good */
                {
                        return;
                }
                send_attach();
                return;
        }
        switch(write_request_sw)
        {
                case 2:         /* completion of arp write */
                        if(data_buf[1]==0)      /* good */
                        {
                                bridge_timer.interval=ARP_TIMEOUT;
                                bridge_timer.periodic=0;
                                bridge_timer.task_adr=0;
                                write_request_sw=3;
                                say("BTS att wr\n");
                                _radio_ss_timer_start(&bridge_timer);
                                return;
                        }
                        write_request_sw=1;
                        if(data_buf[1]!=1)      /* not channel acquire error */
                                send_attach();
                        return;
                case 4:         /* completion of write */
                        if(data_buf[1]==0)      /* good */
                        {
                                evt_set_group(tx_pending,BRG_POST);
                                evt_set_type(tx_pending,TX_DONE);
                                evt_set_error(tx_pending,0);
                                write_request_sw=0;
                                say("TX DONE\n");
                                llc_evt_handler(tx_pending);
                                return;
                        }
                        write_request_sw=1;
```

```
                        i   ry_next_base())
                        {
                                hello_reason_code|=HELLO_REASON_WRITE_ERROR;
                                start_acquire_bases(1);         /* send hello */
                                return;
                        }
                        send_attach();
                        return;
                default:
                        break;
        }

}
/* ****************************************************************** */
static void process_attach_timer_request()
{
        if(write_request_sw==3)         /* arp timeout */
        {
                retry_cnt++;
                if(retry_cnt > ARP_TRIES)
                {
                        evt_set_group(tx_pending,BRG_POST);
                        evt_set_type(tx_pending,TX_DONE);
                        evt_set_error(tx_pending,BRG_ERR_AR_INV_ALIAS);
                        write_request_sw=0;
                        say("TX DONE INV ALIAS\n");
                        llc_evt_handler(tx_pending);
                        return;
                }
                write_request_sw=1;
                ck_for_out_data();
                return;
        }
}
/* ****************************************************************** */
/* ****************************************************************** */
static void send_rarp()
{

        write_base_adr(current_base);
        write_terminal_adr(0x0fff);
        data_buf[0]=BH_WRITE_MULTICAST;
        wrt_int_buf(1,0x06c0);
        wrt_int_buf(3,0x2000);
        wrt_int_buf(5,0x8fff);
        data_buf[7]=0x80;                       /* rarp operation */
        wrt_int_buf(8,0);
        data_buf[10]=2;
        data_buf[11]=6;
        memcpy((unsigned char _far *)&data_buf[12],(unsigned char _far *)termin
        bridge_timer.interval=RARP_TIMEOUT;
        bridge_timer.periodic=0;
        bridge_timer.task_adr=0;
        say("BTS rarp\n");
        _radio_ss_timer_start(&bridge_timer);
        if(alias_len==0)
        {
                data_buf[10]=0x82;
                say("send rarp\n");
                (void)_radio_write(data_buf,18);
```

```
        }
        else
        {
                data_buf[18]=0x87;
                data_buf[19]=(unsigned char)alias_len;
                memcpy((unsigned char _far *)&data_buf[20],(unsigned char _far *
                say("send rarp\n");
                (void)_radio_write(data_buf,18+2+alias_len);
        }
        bridge_state=DETACH_WAITING_FOR_RARP;
}
/* ************************************************************** */
static void send_arp()
{
        char                _far                *arp_adr;
        T_BRG_LLC_FD _far                       *ptr;

        ptr=(T_BRG_LLC_FD _far *)tx_pending->info;
        arp_adr=ptr->alias;
        arp_len=(int)strlen(arp_adr);
        data_buf[0]=BH_WRITE_MODIFY;
        data_buf[1]=15;
        data_buf[2]=25;
        data_buf[3]=80;
        wrt_int_buf(4,0x05c0);
        wrt_int_buf(6,0x2000);
        wrt_int_buf(8,terminal_short_adr);
        data_buf[10]=0x00;                              /* arp operation */
        wrt_int_buf(11,0);
        data_buf[13]=0x0c;
        data_buf[14]=1;
        data_buf[15]=24;
        data_buf[16]=0x87;
        data_buf[17]=(unsigned char)arp_len;
        memcpy((unsigned char _far *)&data_buf[18],(unsigned char _far *)arp_adr
        write_request_sw=2;
        say("send arp\n");
        (void)_radio_write(data_buf,arp_len+18);
}
/* ************************************************************** */
static void send_inquire()
{

        data_buf[0]=BH_WRITE_MODIFY;
        data_buf[1]=12;
        data_buf[2]=25;
        data_buf[3]=80;
        wrt_int_buf(4,0x0088);
        wrt_int_buf(6,current_base);
        wrt_int_buf(8,terminal_short_adr);
        data_buf[10]=0x8c;
        data_buf[11]=1;
        data_buf[12]=24;
        inquire_sw=2;
        say("send inq\n");
        (void)_radio_write(data_buf,13);
}
/* ************************************************************** */
static void send_data()
{
```

```
        T_BRG_LLC_FD _fa.          *ptr;
        T_PACKET _far              *pkt;
        unsigned int               len;


        ptr=(T_BRG_LLC_FD _far *)tx_pending->info;
        pkt=evt_pkt_ptr(tx_pending);
        data_buf[0]=BH_WRITE_MODIFY;
        data_buf[1]=12;
        data_buf[2]=25;
        data_buf[3]=80;
        wrt_int_buf(4,0x0088);
        wrt_int_buf(6,ptr->address);
        wrt_int_buf(8,terminal_short_adr);
        data_buf[10]=0x8c;
        data_buf[11]=1;
        data_buf[12]=24;
        (void)pkt_llc_copy(pkt,(char _far *)&data_buf[13],1100);
        write_request_sw=4;
        len=(unsigned int)pkt_llc_tot_len(pkt);
        if(len > 1090)
        {
                write_request_sw=0;
                evt_set_group(tx_pending,BRG_POST);
                evt_set_type(tx_pending,TX_DONE);
                evt_set_error(tx_pending,BRG_ERR_INVALID_LENGTH);
                say("TX DONE INVALID LENGTH ");
                sayword(len);
                say("\n");
                llc_evt_handler(tx_pending);
                return;
        }
        say("send datalen=");
        sayword(len);
        say("\n");
        (void)_radio_write(data_buf,(int)(len+13));
}
/*********************************************************************** */
static void send_attach()
{

        _radio_ss_timer_stop(&bridge_timer);
        _radio_ss_timer_stop(&attach_timer);
        attach_request_sw=0xff;
        write_base_adr(current_base);
        data_buf[0]=BH_WRITE_MODIFY;
        data_buf[1]=15;
        data_buf[2]=25;
        data_buf[3]=80;
        wrt_int_buf(4,0x03c0);
        wrt_int_buf(6,0x2000);
        wrt_int_buf(8,terminal_short_adr);
        data_buf[10]=0x0f;        /* max mesg count */
        data_buf[11]=1;
        data_buf[12]=3;
        data_buf[13]=0x0c;
        data_buf[14]=1;
        data_buf[15]=24;
        data_buf[16]=0x8e;        /* delivery type */
        data_buf[17]=1;
```

```
        data_buf[18]=2;
        say("send attach\n");
        (void)_radio_write(data_buf,19);
        attach_timeout_type_sw=0;
        bridge_state=DETACH_WAITING_FOR_ATTACH;
}
/* ****************************************************************** */
static void send_hello()
{

        _radio_ss_timer_stop(&bridge_timer);
        write_base_adr(0x27ff);         /* any base address */
        data_buf[0]=BH_WRITE_MULTICAST;
        wrt_int_buf(1,0x0280);
        wrt_int_buf(3,0xffff);
        wrt_int_buf(5,(0x8000 | hello_reason_code));
        data_buf[7]=0x8d;
        data_buf[8]=1;
        data_buf[9]=0;
        say("send hello\n");
        (void)_radio_write(data_buf,10);
        bridge_state=DETACH_WAITING_FOR_HELLO_WRITE;
        hello_reason_code=0;
}
/* ****************************************************************** */
static int find_rarp_optional_parm(pos)
        int     pos;
{
        if(pos==0)
        {
                if(data_buf[BRIDGE_CONTROL+1] & 0x80)
                {
                        return(BRIDGE_PACKET_PARMS+3);
                }
                return(-1);
        }
        if(data_buf[pos] & 0x80)return(-1);
        return(pos+2+data_buf[pos+1]);
}
/* ****************************************************************** */
static void ck_for_out_data()
{
        T_BRG_LLC_FD _far       *ptr;

        if(inquire_sw > 1)return;
        if(write_request_sw > 1)return;
        if(attach_request_sw)
        {
                if(attach_request_sw==1)        /* normal attach request */
                {
                        if(link_status_sw==LINK_DISABLED)
                        {
                                inquire_sw=0;
                                write_request_sw=0;
                                start_acquire_bases(1);         /* send hello */
                                return;
                        }
                        send_attach();
                }
                if(attach_request_sw==2)        /* attach to next base */
```

```
                {       (link_status_sw==LINK_DIS   ED)
                        {
                                inquire_sw=0;
                                write_request_sw=0;
                                start_acquire_bases(1);         /* send hello *
                                return;
                        }
                        if(try_next_base())
                        {
                                attach_request_sw=0;
                                hello_reason_code|=HELLO_REASON_ATTACH_3;
                                start_acquire_bases(0);
                                return;
                        }
                        send_attach();
                }
                return;
        }
        if(link_status_sw==LINK_DISABLED)
        {
                inquire_sw=0;
                write_request_sw=0;
                start_acquire_bases(1);         /* send hello */
                return;
        }
        if(bridge_state != ATTACH)return;
        if(write_request_sw)
        {
                inquire_sw=0;
                ptr=(T_BRG_LLC_FD _far *)tx_pending->info;
                if(ptr->address==0)
                {
                        send_arp();
                        return;
                }
                send_data();
                return;
        }
        if(inquire_sw)
        {
                send_inquire();
                return;
        }
}
/* *********************************************************** */
static int try_next_base()
{
//      return 1 if no base available
//      return 0 if base available

        if(next_base_valid==0)return(1);
        next_base_valid=0;
        current_base=next_base;
        memcpy(current_cost,next_cost,2);
        current_strength=next_strength;
        return(0);
}
/* *********************************************************** */
static void wrt_int_buf(indx,data)
```

```
	int		i  ;
	unsigned int	data;
{
	data_buf[indx++]=(unsigned char)(data >> 8);
	data_buf[indx]=(unsigned char)(data & 0x00ff);

}
/* **************************************************************** */
static void sort_bases()
{
	int		i,j,k,sort_sw;
	unsigned char	buf[sizeof(struct BASE_INFO)];

	if(base_ptr < 2)return;
	j=base_ptr-1;
	for(;;)
	{
		for(i=0,sort_sw=0;i<j;i++)
		{
			k=memcmp((unsigned char _far *)&bases[i],(unsigned char
			if(k > 0)
			{
				sort_sw=1;
				memcpy((unsigned char _far *)buf,(unsigned char
				memcpy((unsigned char _far *)&bases[i],(unsigned
				memcpy((unsigned char _far *)&bases[i+1],(unsign
			}
		}
		if(!(sort_sw))return;
		j--;
	}
}
/* **************************************************************** */
static void write_terminal_adr(adr)
	unsigned int	adr;
{

	temp_out_buf[0]=BH_WRITE_SHORT_ADDR;
	temp_out_buf[1]=adr >> 8;
	temp_out_buf[2]=adr & 0x00ff;
	say("write term adr ");
	sayword(adr);
	say("\n");
	(void)_radio_write(temp_out_buf,3);
}
/* **************************************************************** */
static void write_base_adr(adr)
	unsigned int	adr;
{

	temp_out_buf[0]=BH_WRITE_BASE_ADDR;
	temp_out_buf[1]=adr >> 8;
	temp_out_buf[2]=adr & 0x00ff;
	memcpy(&temp_out_buf[3],current_cost,2);
	temp_out_buf[5]=current_strength;
	say("write base adr ");
	sayhex(temp_out_buf,6);
	say("\n");
	(void)_radio_write(temp_out_buf,6);
}
/* **************************************************************** */
```

```
static void write_lan_ad   r)
        unsigned int    adr;
{

        adr &=3;
        temp_out_buf[0]=BH_WRITE_LAN_ADDR;
        temp_out_buf[1]=(unsigned char)adr;
        say("write lan adr ");
        sayword(adr);
        say("\n");
        (void)_radio_write(temp_out_buf,2);
}
/* *************************************************************** */
static void disable_mac()
{

        temp_out_buf[0]=BH_COMM_DISABLE;
        say("disable\n");
        (void)_radio_write(temp_out_buf,1);
}
/* *************************************************************** */
static void load_code(code)
        unsigned char   code;
{

        temp_out_buf[0]=BH_CODE_LOAD;
        temp_out_buf[1]=code;
        (void)_radio_write(temp_out_buf,2);
}
/* *************************************************************** */
static void enable_mac()
{

        temp_out_buf[0]=BH_COMM_ENABLE;
        say("enable\n");
        (void)_radio_write(temp_out_buf,1);
}
/* *************************************************************** */
static int rd_long_id()
{
        int     i;

        temp_out_buf[0]=BH_RD_LONG_ID;
        i=_radio_write(temp_out_buf,1);
        if(i <0)return(-1);
        i=_radio_read(temp_in_buf,20);
        if(i < 0)return(-1);
        if(temp_in_buf[0]==BH_ROM_CODE_VERSION)return(1);
        if(temp_in_buf[0]!=BH_RD_LONG_ID)return(2);
        if(i != 10)return(3);
        if(temp_in_buf[8] != temp_in_buf[9])return(3);
        memcpy((unsigned char _far *)terminal_long_id,(unsigned char _far *)&te
        memcpy((unsigned char _far *)sst_version.long_id,(unsigned char _far *)
        return(0);
}
/* *************************************************************** */
static int rd_version()
{
        int     i;
        unsigned int    j;
```

```
        temp_out_buf[0]=B.._RD_VERSION;
        i= radio_write(temp_out_buf,1);
        if(i <0)return(-1);
        i= radio_read(temp_in_buf,20);
        if(i < 0)return(-1);
        if(temp_in_buf[0]==BH_ROM_CODE_VERSION)return(-2);
        if(temp_in_buf[0]!=BH_RD_VERSION)return(0);
        if(i != 3)return(0);
        j=temp_in_buf[2];
        j<<=8;
        j |= temp_in_buf[1];
        return((int)j);
                                                                        */
* ******************************************************************* */
tatic int sst_self_test_1()

        int     i;

        temp_out_buf[0]=BH_SELF_TEST_1;
        temp_out_buf[1]=spread_code;
        i= radio_write(temp_out_buf,2);
        if(i <0)return(-1);
        small_delay();
        i= radio_read(temp_in_buf,20);
        if(i < 0)return(-1);
        if(temp_in_buf[0]==BH_ROM_CODE_VERSION)return(-2);
        if(temp_in_buf[0]!=BH_SELF_TEST_1)return(1);
        if(i != 2)return(1);
        return((int)temp_in_buf[1]);
                                                                        */
/* ******************************************************************* */
static int sst_self_test_2()
{
        int     i;

        temp_out_buf[0]=BH_SELF_TEST_2;
        temp_out_buf[1]=spread_code;
        i= radio_write(temp_out_buf,2);
        if(i <0)return(-1);
        small_delay();
        i= radio_read(temp_in_buf,20);
        if(i < 0)return(-1);
        if(temp_in_buf[0]==BH_ROM_CODE_VERSION)return(-2);
        if(temp_in_buf[0]!=BH_SELF_TEST_2)return(1);
        if(i != 2)return(1);
        return((int)temp_in_buf[1]);
}
/* ******************************************************************* */
static int sst_rd_rssi_table()
{
        int             i;
        int             j;
        unsigned char   lrc;

        for(i=0;i<31;i++)
        {
                temp_out_buf[0]=BH_RD_EEPROM;
                temp_out_buf[1]=(unsigned char)i;
                j=_radio_write(temp_out_buf,2);
```

```
            if(j <0)
            {
                    say("rssi write fault ");
                    sayword(i);
                    say("\n");
                    return(-1);
            }
            j=_radio_read(temp_in_buf,20);
            if(j < 0)
            {
                    say("rssi read fault ");
                    sayword(i);
                    say("\n");
                    return(-1);
            }
            if(temp_in_buf[0]==BH_ROM_CODE_VERSION)return(-2);
            if(temp_in_buf[0]!=BH_RD_EEPROM)return(1);
            if(j != 2)return(1);
            rssi_tab[i]=temp_in_buf[1];
    }
    for(i=0,lrc=47;i<30;i++)
    {
            lrc ^= rssi_tab[i];
    }

    if(lrc != rssi_tab[30])return(1);
    rssi_valid=1;
    return(0);
}
/* ************************************************************** */
static int sst_self_test_tx_power()
{
    int             j;

    load_code(spread_code);
    temp_out_buf[0]=BH_RD_TX_POWER;
    j=_radio_write(temp_out_buf,1);
    if(j <0)
    {
            say("sst_self_test_tx_power-1\n");
            return(-1);
    }
    j=_radio_read(temp_in_buf,20);
    if(j < 0)
    {
            say("sst_self_test_tx_power-2\n");
            return(-1);
    }
    if(temp_in_buf[0]==BH_ROM_CODE_VERSION)
    {
            say("sst_self_test_tx_power-3\n");
            return(-2);
    }
    say("sst_self_test_tx_power-4\n");
    if(temp_in_buf[0]!=BH_RD_TX_POWER)return(1);
    say("sst_self_test_tx_power-5\n");
    if(rssi_tab[21]>temp_in_buf[1])return(1);
    say("sst_self_test_tx_power-6\n");
    return(0);
}
```

```
/* *********************    *************************,    ********** */
static void small_delay()
{
	int	i;

	for(i=0;i<30000;i++)
	{
	}
}
/* ************************************************************** */
static void set_power_management(type)
	unsigned char	type;
{

	temp_out_buf[0]=BH_HELLO_HANDLE;
	temp_out_buf[1]=type;
	temp_out_buf[2]=(unsigned char)root_seq_number;
	temp_out_buf[3]=(unsigned char)root_id_len;
	if(root_id_len)
	{
		memcpy((unsigned char _far *)&temp_out_buf[4],(unsigned char _fa
	}
	say("power management ");
	sayword(type);
	say("\n");
	(void)_radio_write(temp_out_buf,(int)(root_id_len+4));
}
/* ************************************************************** */
static void post_llc(code)
	unsigned int	code;
{
	T_EVENT _far	*ptr;

	ptr=event_get();
	if(ptr==0)
	{
		say("POST LLC event get error\n");
		return;
	}
	evt_set_group(ptr,BRG_POST);
	evt_set_type(ptr,ERROR);
	evt_set_error(ptr,code);
	say("POST LLC ");
	sayword(code);
	say("\n");
	llc_evt_handler(ptr);
}
/* ************************************************************** */
/*		call after SERIAL_READ from _wait			*/
/* ************************************************************** */
static void	(*state_table[])()=
		{
			state_detach,
			state_detach_hello_write,
			state_detach_waiting_for_hello,
			state_detach_waiting_for_rarp,
			state_detach_waiting_for_attach,
			state_detach_backoff,
			state_attach
		};
```

```
* ******************************************************************** */
static void process_bridge(type)
        int     type;

        void    (*state_call)();

        state_call=state_table[bridge_state];
        (*state_call)(type);
}
/* ******************************************************************** */
void _radio_ss_bridge_shutdown()
{
        alias_len=0;
        disable_mac();
        _radio_ss_timer_stop(&bridge_timer);
        _radio_ss_timer_stop(&attach_timer);
        _radio_ss_timer_delete(&bridge_timer);
        _radio_ss_timer_delete(&attach_timer);
        attach_request_sw=0;
        write_request_sw=0;
        root_seq_number=-1;
        bridge_state=DETACH;
}
/* ******************************************************************** */
SST_VERSION_CONTROL _far *_radio_ss_bridge_init(
        unsigned int            lan,
        unsigned char _far      *alias
        )
{
        int     i;
        int     j;
        T_EVENT _far    *evt;
        int     code_load_sw;

        spread_code=SPREAD_CODE;
        alias_len=0;
        i=(int)strlen((char _far *)alias);
        _radio_ss_timer_init();
        if(i <= 16)
        {
                strcpy(alias_name,alias);
                alias_len=i;
        }
        _radio_ss();
        sst_version.sst_hardware_errors_major=0;
        if(!(first_time_sw))
        {
                first_time_sw=1;
                sst_version.sst_hardware_errors_minor=0;
                sst_version.sst_h8_rom_code_version=0;
                sst_version.sst_h8_ram_code_version=0;
                sst_version.sst_bridge_code_version=VERSION;
                say("Bridge version=");
                sayword(VERSION);
                say("\n");
                sst_version.sst_digital_board_type=0;
                sst_version.base_short_addr=0;
                sst_version.term_short_addr=0;
                sst_version.link_status=0;
```

```
        sst_versi   rssi_a_to_d_value=0;
        memset(sst_version.long_id,0,6);
}
code_load_sw=0;
for(i=0;i<10;i++)
{
        j=_radio_read(data_buf,1200);
        if(j < 0)
        {
                say("rd ver i= ");
                sayword(i);
                say("\n");
                sst_version.sst_hardware_errors_major=SST_ERROR_MODULE_N
                return(&sst_version);
        }
        if(j==0)
        {
                code_load_sw=1;
                break;
        }
        if(data_buf[0]==BH_ROM_CODE_VERSION)
        {
                sst_version.sst_h8_rom_code_version=data_buf[1];
                say("H8 version=");
                sayword(data_buf[1]);
                say("\n");
                break;
        }
}
if(i >= 10)
{
        sst_version.sst_hardware_errors_major=SST_ERROR_UNABLE_TO_CLR_BU
        return(&sst_version);
}
say("h8 version=");
sayword(sst_version.sst_h8_rom_code_version);
say("\n");
if(!(code_load_sw))
{
        say("I1\n");
        i=_sst_h8_code_load();
        if(i != 0)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_UNABLE_T
                return(&sst_version);
        }
        i=rd_version();
        say("I2\n");
        if(i == -1)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_MODULE_N
                return(&sst_version);
        }
        if(i == -2)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_UNABLE_
                return(&sst_version);
        }
        if(i == 0)
        {
```

```
        s  version.sst_hardware_err   _major=SST_ERROR_INVALID_
        return(&sst_version);
}
sst_version.sst_h8_ram_code_version=(unsigned char)(i & 0x00ff);
say("H8 ram code version = ");
sayword(i & 0x00ff);
say("\n");
sst_version.sst_digital_board_type=(unsigned char)((unsigned int
sst_version.sst_hardware_errors_minor=0;
if(sst_version.sst_digital_board_type >= 2)
{
        say("I3\n");
        i=sst_self_test_1();
        if(i == -1)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_
                return(&sst_version);
        }
        if(i == -2)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_
                return(&sst_version);
        }
        if(i)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_
                return(&sst_version);
        }
        say("I4\n");
        i=sst_self_test_2();
        if(i == -1)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_
                return(&sst_version);
        }
        if(i == -2)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_
                return(&sst_version);
        }
        if(i)
        {
                sst_version.sst_hardware_errors_minor |= SST_ERR
        }
        say("I5\n");
        i=sst_rd_rssi_table();
        if(i == -1)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_
                say("I5a\n");
                return(&sst_version);
        }
        if(i == -2)
        {
                sst_version.sst_hardware_errors_major=SST_ERROR_
                say("I5b\n");
                return(&sst_version);
        }
        if(i)
        {
```

```
                                        sst_version.sst_hard    e_errors_minor |= SST_ERR
                                }
                                else
                                {
                                        say("I6\n");
                                        i=sst_self_test_tx_power();
                                        if(i == -1)
                                        {
                                                sst_version.sst_hardware_errors_major=SS
                                                say("I6a\n");
                                                return(&sst_version);
                                        }
                                        if(i == -2)
                                        {
                                                sst_version.sst_hardware_errors_major=SS
                                                say("I6b\n");
                                                return(&sst_version);
                                        }
                                        if(i)
                                        {
                                                sst_version.sst_hardware_errors_minor |=
                                        }
                                }
                        }
                }
                say("I7\n");
                i=rd_long_id();
                if(i < 0)
                {
                        sst_version.sst_hardware_errors_major=SST_ERROR_MODULE_NON_RESPC
                        return(&sst_version);
                }
                if(i == 1)
                {
                        sst_version.sst_hardware_errors_major=SST_ERROR_UNABLE_TO_LOAD_C
                        return(&sst_version);
                }
                if(i != 0)
                {
                        sst_version.sst_hardware_errors_major=SST_ERROR_INVALID_LONG_ID;
                        return(&sst_version);
                }
                load_code(spread_code);
                disable_mac();
                write_lan_adr(lan);
                attach_request_sw=0;
                write_request_sw=0;
                root_id_len=0;
                root_seq_number=-1;
                (void)_radio_ss_timer_create(&bridge_timer);
                (void)_radio_ss_timer_create(&attach_timer);
                (void)_radio_ss_timer_create(&attach_backoff_timer);
                attach_timer.interval=ATTACH_TIMEOUT;
                attach_timer.periodic=0;
                attach_timer.task_adr=0;
                attach_backoff_timer.interval=ATTACH_BACKOFF_TIMEOUT;
                attach_backoff_timer.periodic=0;
                attach_backoff_timer.task_adr=0;
                write_terminal_adr(0xffff);
                hello_reason_code=HELLO_REASON_INIT;
```

```
    link_status_sw=L  DISABLED;
    start_acquire_bases(1);          /* send hello */
    return(&sst_version);

/* ****************************************************************** */
void _radio_ss_bridge_interrupt()
{
    unsigned int    i;
    unsigned int    j;

    for(;;)
    {
            i=(unsigned int)_radio_read(data_buf,1200);
            data_in_len=i;
            if(!(i & 0x8000))break;
            say("radio read--error ");
            sayword(i);
            say("\n");
    }
    if(i==0)
    {
            say(".");
            return;
    }
    j=20;
    say("s=");
    sayword(bridge_state);
    say(" len=");
    sayword(i);
    say(" LS=");
    sayword(link_status_sw);
    say("\n");
    if(i<j)j=i;
    sayhex(data_buf,j);
    say("\n");
    switch(data_buf[0])
    {
            case BH_TIMER:
                            _radio_ss_update_timers(data_buf[1]);
                            if(_radio_ss_timer_stopped(&bridge_timer))
                            {
                                    say("BT\n");
                                    process_bridge(TIMER);
                            }
                            if(_radio_ss_timer_stopped(&attach_timer))
                            {
                                    say("AT\n");
                                    process_bridge(ATTACH_TIMER);
                            }
                            break;
            case BH_READ:
                            sst_version.rssi_a_to_d_value=data_buf[5];
                            process_bridge(DATA);
                            break;
            case BH_WRITE:
                            process_bridge(WRITE_RESPONSE);
                            break;
            case BH_HELLO_TIMEOUT:
                            say("BH_HELLO_TIMEOUT\n");
                            if(bridge_state==ATTACH)
```

```
                {
                        if(write_request_sw==0)
                                post_llc(BRG_ERR_ATTI);
                }
                break;
        case BH_BASE_INFO:
                say("BH_BASE_INFO\n");
                i=data_buf[1];
                i <<= 8;
                i |= data_buf[2];
                if(i==0)
                {
                        next_base_valid=0;
                        break;
                }
                next_base=i;
                next_cost[0]=data_buf[3];
                next_cost[1]=data_buf[4];
                next_strength=data_buf[5];
                next_base_valid=1;
                say("next base=");
                sayword(next_base);
                say("\n");
                break;
        default:
                say("UNKNOWN 1\n");
                break;
    }
    say("ES=");
    sayword(bridge_state);
    say(" ");
    sayword(write_request_sw);
    say(" ");
    sayword(attach_request_sw);
    say("\n");
    switch(bridge_state)
    {
        case DETACH:
                sst_version.link_status=LINK_DETACH;
                break;
        case ATTACH:
                sst_version.link_status=LINK_OK;
                break;
        default:
                sst_version.link_status=LINK_QUESTIONABLE;
                break;
    }
}
/* ************************************************************* */
void _far brg_evt_handler(T_EVENT _far *evt)
{
    say("B1\n");
    if(evt_type(evt) == TX_REQ)
    {
        if(link_status_sw==LINK_DISABLED)
        {
                say("tx_done--link disabled\n");
                evt_set_group(tx_pending,BRG_POST);
                evt_set_type(tx_pending,TX_DONE);
                evt_set_error(evt,BRG_ERR_LINK_DISABLED);
```

006190.71676560

```
                    llc_evt_handler(evt);
                    return;
            }
            if(write_request_sw)
            {
                    say("tx_done--brg_err_busy\n");
                    evt_set_group(tx_pending,BRG_POST);
                    evt_set_type(tx_pending,TX_DONE);
                    evt_set_error(evt,BRG_ERR_BUSY);
                    llc_evt_handler(evt);
                    return;
            }
            tx_pending=evt;
            write_request_sw=1;
            say("B1 state=");
            sayword(bridge_state);
            say("\n");
            if(bridge_state==ATTACH)
                    ck_for_out_data();
            return;
    }
    say("B2\n");

}
/* ****************************************************************** */
```

```
/* ********************** ****************************** */
/*  MAC layer process                                      */
/* ****************************************************** */
#define EXTERN
#include              "ssh8.h"
/* ************************************************************** */
static void set_mac_backoff_time(unsigned int,unsigned int);
static int mac_acquire_channel();
static void send_multicast_msg();
static void mac_send_rfp();
static void set_mac_timer();
static void reset_mac_timer();
static void send_ss_data();
extern void process_bridge_layer();
static void process_mac_idle();
static void process_mac_tx_machine();
static void process_mac_rx_machine();
static void process_mac_layer_data_entry();
static void process_mac_rx_timeout();
static void process_mac_layer_timeout();
static void process_mac_tx_ready();
static void process_mac_tx_s_data();
static void process_mac_tx_s_eod();
static void process_mac_tx_rdy_enq();
static void process_mac_tx_s_enq();
static void process_mac_tx_s_rfp();
static void process_tx_send_record();
static int ck_tx_seq_state();
static void mac_send_enq();
static void mac_send_poll();
static void mac_send_clear();
static void mac_send_reject();
static void ss_write_control();
void ss_set_standby();
static unsigned char check_address();
void set_ignore_c188_timer(unsigned char);
/* ************************************************************* */
extern void     (*hdlc_write_data_ptr)(unsigned char *,unsigned char *,unsigned
/* ************************************************************* */
extern unsigned char    hdlc_data_in_buf[];
extern unsigned char    mac_timer_flag;
extern unsigned char            mac_rx_strength;
/* ************************************************************* */
static void check_tx_pending()
{
        if(!(u.s.tx_pending_sw))return;
        u.s.mac_state=MAC_TX_MACHINE;
        u.s.mac_retry_cnt=0;
        u.s.mac_acq_retry_cnt=0;
        u.s.mac_wait_cnt=0;
        set_mac_backoff_time(0,T_4_MILLI);
        u.s.mac_tx_state=TX_READY;
}
/* ************************************************************** */
static void process_mac_bridge_interface(size)
        int     size;
{
        if((size & 0x7fff) == 0)return;
        u.s.mac_tx_size=(unsigned int)size;
        u.s.mac_tx_ptr=0;
```

```
        if(u.s.mac_state=     C_RX_MACHINE)
        {
                u.s.tx_pending_sw=1;
                return;
        }
        u.s.mac_state=MAC_TX_MACHINE;
        u.s.mac_retry_cnt=0;
        u.s.mac_acq_retry_cnt=0;
        set_mac_backoff_time(0,T_4_MILLI);
        u.s.mac_tx_state=TX_READY;
        return;
}
/* ************************************************************ */
static void send_multicast_msg()
{
        unsigned char   control;
        unsigned int    size;

        reset_mac_timer();
        size=u.s.mac_tx_size & 0x7fff;
        if(size < 100)
        {
                control = u.s.lan_address;
                send_ss_data(control,(unsigned char)size,bridge_tx_buffer,(unsig
                u.s.mac_state=MAC_IDLE;
                process_bridge_layer(MAC,MAC_TX_COMPLETE,0);
        }
}
/* ************************************************************ */
static void process_mac_layer_data_entry(size)
        int             size;
{

        switch(u.s.mac_state)
        {
                case MAC_IDLE:
                                if(u.s.mac_dest_adr & 0x8000)
                                {
                                        if((u.s.mac_source_adr & 0x7800) != 0x2(
                                }
                                else
                                {
                                        if(check_address())return;
                                }
                                process_mac_idle(size);
                                break;
                case MAC_TX_MACHINE:
                                process_mac_tx_machine(DATA,size);
                                break;
                case MAC_RX_MACHINE:
                                if(check_address())return;
                                process_mac_rx_machine(size);
                                break;
                default:
                                return;
        }
}
/* ************************************************************ */
void set_ignore_c188_timer(unsigned char time)
{
```

```
        t0tcr=0;
        t0tcora=time;
        t0tcnt=0;
        t0tcsr &= 0x1f;
        t0tcr=0x03;

* ************************************************************** */
static unsigned char check_address()

        if((u.s.short_address) != (u.s.mac_dest_adr & 0x7fff))
                return(1);
        if(u.s.mac_source_adr != u.s.base_address)
                return(1);
        return(0);

* ************************************************************** */
static void process_mac_layer_timeout()

        switch(u.s.mac_state)
        {
                case MAC_IDLE:
                                reset_mac_timer();
                                break;
                case MAC_TX_MACHINE:
                                process_mac_tx_machine(TIMER,0);
                                break;
                case MAC_RX_MACHINE:
                                process_mac_rx_timeout();
                                break;
                default:
                                return;
        }

* ************************************************************** */
tatic void process_mac_tx_machine(type,size)
        int     type;
        int     size;

        switch(u.s.mac_tx_state)
        {
                case TX_READY:
                                process_mac_tx_ready(type,size);
                                return;
                case TX_S_RFP:
                                process_mac_tx_s_rfp(type,size);
                                return;
                case TX_S_DATA:
                                process_mac_tx_s_data(type);
                                return;
                case TX_S_EOD:
                                process_mac_tx_s_eod(type,size);
                                return;
                case TX_RDY_ENQ:
                                process_mac_tx_rdy_enq(type,size);
                                return;
                case TX_S_ENQ:
                                process_mac_tx_s_enq(type,size);
                                return;
                default:
                                return;
```

```
	}
* ************************************************************** */
:atic void process_mac_tx_ready(type,size)
	int	type;
	int	size;

	unsigned int	time;
	unsigned int	rand_time;

	if(type==TIMER)
	{
		reset_mac_timer();
		if(!(mac_acquire_channel()))
		{
			u.s.mac_acq_retry_cnt++;
			if(u.s.mac_acq_retry_cnt >= MAX_TX_ACQUIRE_TRIES)
			{
				u.s.tx_pending_sw=0;
				u.s.mac_state=MAC_IDLE;
				process_bridge_layer(MAC,MAC_TX_ACQUIRE_FAILURE,
				return;
			}
			time=T_2_MILLI;
			rand_time=T_4_MILLI;
			if(u.s.mac_acq_retry_cnt > 4)
			{
				time=T_6_MILLI;
				rand_time=T_10_MILLI;
			}
			if(u.s.mac_acq_retry_cnt > 10)
			{
				time=T_16_MILLI;
				rand_time=T_16_MILLI;
			}

			set_mac_backoff_time(time,rand_time);
			return;
		}
		if(u.s.mac_tx_size & 0x8000)		/* multicast */
		{
			u.s.tx_pending_sw=0;
			send_multicast_msg();
			return;
		}
		u.s.mac_tx_state=TX_S_RFP;
		mac_send_rfp();
		set_mac_timer(RSP_TIMEOUT);
		return;
	}
	if(type==DATA)
	{
		if(u.s.mac_dest_adr & 0x8000)
		{
			if((u.s.mac_source_adr & 0x7800) != 0x2000)return;
		}
		else
		{
			if(check_address())
			{
```

```
                        return;
                }
        }
        reset_mac_timer();
        u.s.tx_pending_sw=1;
        process_mac_idle(size);
}

* ************************************************************** */
tatic void process_mac_tx_s_rfp(type,size)
        int     type;
        int     size;

        if(type==TIMER)
        {
                u.s.mac_retry_cnt++;
                if(u.s.mac_retry_cnt >= MAX_TX_RFP_TRIES)
                {
                        u.s.tx_pending_sw=0;
                        reset_mac_timer();
                        u.s.mac_state=MAC_IDLE;
                        process_bridge_layer(MAC,MAC_TX_RFP_FAILURE,0);
                        return;
                }
                u.s.mac_tx_state=TX_READY;
                set_mac_backoff_time(0,T_4_MILLI);
                return;
        }                                                       /* data record */

        if(check_address())return;

        switch(u.s.mac_control & 0xe0)
        {                                                       /* poll */
                case 0xe0:
                                u.s.tx_pending_sw=0;
                                u.s.mac_retry_cnt=0;
                                process_tx_send_record();
                                return;
                case 0x60:                                      /* rfp */
                                reset_mac_timer();
                                u.s.tx_pending_sw=1;
                                process_mac_idle(size);
                                return;
                default:
                                break;
        }
}
/* ************************************************************** */
static void process_mac_tx_s_data(type)
        int     type;
{
        if(type==TIMER)
        {
                reset_mac_timer();
                u.s.mac_retry_cnt++;
                if(u.s.mac_retry_cnt < MAX_TX_TRIES)
                {
                        set_mac_timer(POLL_TIMEOUT);
                        return;
```

```
            }
            u.s.mac_state=MAC_IDLE;
            process_bridge_layer(MAC,MAC_TX_FAILURE,0);
            return;
    }
    if(check_address())return;

    if((u.s.mac_control & 0xe0) == 0xe0)                /* poll record */
    {
            if(ck_tx_seq_state())
            {
                    u.s.mac_retry_cnt=0;
                    u.s.mac_tx_seq_state++;
                    u.s.mac_tx_seq_state &= 1;
                    u.s.mac_tx_ptr += 100;
            }
            else
            {
                    u.s.mac_retry_cnt++;
                    if(u.s.mac_retry_cnt >= MAX_TX_TRIES)
                    {
                            reset_mac_timer();
                            u.s.mac_state=MAC_IDLE;
                            process_bridge_layer(MAC,MAC_TX_FAILURE,0);
                            return;
                    }
            }
            process_tx_send_record();
            return;
    }
    reset_mac_timer();
    u.s.mac_state=MAC_IDLE;
    process_bridge_layer(MAC,MAC_TX_SEQ_FAILURE,0);
}
/* ************************************************************* */
static void process_mac_tx_s_eod(type,size)
    int     type;
    int     size;
{
    if(type==TIMER)
    {
            u.s.mac_retry_cnt++;
            if(u.s.mac_retry_cnt >= MAX_IDLE_TRIES)
            {
                    reset_mac_timer();
                    u.s.mac_state=MAC_IDLE;
                    process_bridge_layer(MAC,MAC_TX_COMPLETE_QUESTION,0);
                    return;
            }
            u.s.mac_tx_state=TX_RDY_ENQ;
            set_mac_backoff_time(0,T_4_MILLI);
            return;
    }
    if(check_address())return;

    if((u.s.mac_control & 0xe0) == 0xe0)                /* poll */
    {
            if(ck_tx_seq_state())
            {
                    reset_mac_timer();
```

```
                u.s.mac_state=MAC_IDLE;
                process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
                return;
            }
            u.s.mac_retry_cnt++;
            if(u.s.mac_retry_cnt >= MAX_TX_TRIES)
            {
                reset_mac_timer();
                u.s.mac_state=MAC_IDLE;
                process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
                return;
            }
            process_tx_send_record();
            return;
        }
        if((u.s.mac_control & 0xe0) == 0xc0)            /* clear */
        {
            if(ck_tx_seq_state())
            {
                reset_mac_timer();
                u.s.mac_tx_seq_state++;
                u.s.mac_tx_seq_state &= 1;
                u.s.mac_state=MAC_IDLE;
                process_bridge_layer(MAC,MAC_TX_COMPLETE,0);
                return;
            }
            else
            {
                reset_mac_timer();
                u.s.mac_state=MAC_IDLE;
                process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
                return;
            }
        }
        if((u.s.mac_control & 0xe0)== 0x60)     /* rfp */
        {
            reset_mac_timer();
            u.s.mac_state=MAC_IDLE;
            process_bridge_layer(MAC,MAC_TX_COMPLETE,0);
            process_mac_idle(size);
            return;
        }
        reset_mac_timer();
        u.s.mac_state=MAC_IDLE;
        process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
}
/* ************************************************************* */
static int ck_tx_seq_state()
{
        if(u.s.mac_tx_seq_state & 1)
        {
            if(u.s.mac_control & 0x10)      /* seq */
                return(0);
            else
                return(1);
        }
        if(u.s.mac_control & 0x10)      /* seq */
            return(1);
        return(0);
}
```

```
/* ******************************************************************* */
static void process_mac_tx_rdy_enq(type,size)
        int     type;
        int     size;
{
        if(type==TIMER)
        {
                u.s.mac_retry_cnt++;
                if(u.s.mac_retry_cnt >= MAX_TX_TRIES)
                {
                        reset_mac_timer();
                        u.s.mac_state=MAC_IDLE;
                        process_bridge_layer(MAC,MAC_TX_COMPLETE_QUESTION,0);
                        return;
                }
                if(!(mac_acquire_channel()))
                {
                        set_mac_backoff_time(0,T_4_MILLI);
                        return;
                }
                u.s.mac_retry_cnt++;
                mac_send_enq();
                set_mac_timer(RSP_TIMEOUT);
                u.s.mac_tx_state=TX_S_ENQ;
                return;
        }
        if(check_address())return;

        if((u.s.mac_control & 0xe0) == 0xe0)            /* poll */
        {
                if(ck_tx_seq_state())
                {
                        reset_mac_timer();
                        u.s.mac_state=MAC_IDLE;
                        process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
                        return;
                }
                u.s.mac_retry_cnt++;
                if(u.s.mac_retry_cnt >= MAX_TX_TRIES)
                {
                        reset_mac_timer();
                        u.s.mac_state=MAC_IDLE;
                        process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
                        return;
                }
                process_tx_send_record();
                return;
        }
        if((u.s.mac_control & 0xe0) == 0xc0)            /* clear */
        {
                if(ck_tx_seq_state())
                {
                        reset_mac_timer();
                        u.s.mac_tx_seq_state++;
                        u.s.mac_tx_seq_state &= 1;
                        u.s.mac_state=MAC_IDLE;
                        process_bridge_layer(MAC,MAC_TX_COMPLETE,0);
                        return;
                }
                else
```

```
            {
                    reset_mac_timer();
                    u.s.mac_state=MAC_IDLE;
                    process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
                    return;
            }
    }
    if((u.s.mac_control & 0xe0)== 0x60)      /* rfp */
    {
            reset_mac_timer();
            u.s.mac_state=MAC_IDLE;
            process_bridge_layer(MAC,MAC_TX_COMPLETE,0);
            process_mac_idle(size);
            return;
    }
    reset_mac_timer();
    u.s.mac_state=MAC_IDLE;
    process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
}
/* *************************************************************** */
static void process_mac_tx_s_enq(type,size)
        int     type;
        int     size;
{
        if(type==TIMER)
        {
                u.s.mac_retry_cnt++;
                if(u.s.mac_retry_cnt >= MAX_TX_TRIES)
                {
                        reset_mac_timer();
                        u.s.mac_state=MAC_IDLE;
                        process_bridge_layer(MAC,MAC_TX_COMPLETE_QUESTION,0);
                        return;
                }
                if(!(mac_acquire_channel()))
                {
                        set_mac_backoff_time(0,T_4_MILLI);
                        return;
                }
                mac_send_enq();
                set_mac_timer(RSP_TIMEOUT);
                u.s.mac_tx_state=TX_S_ENQ;
                return;
        }
        if(check_address())return;

        if((u.s.mac_control & 0xe0) == 0xe0)            /* poll */
        {
                if(ck_tx_seq_state())
                {
                        reset_mac_timer();
                        u.s.mac_state=MAC_IDLE;
                        process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
                        return;
                }
                u.s.mac_retry_cnt++;
                if(u.s.mac_retry_cnt >= MAX_TX_TRIES)
                {
                        reset_mac_timer();
                        u.s.mac_state=MAC_IDLE;
```

```
	                ess_bridge_layer(MAC,MAC     _EOD_FAILURE,0);
	                return;
	        }
	        process_tx_send_record();
	        return;
	}
	if((u.s.mac_control & 0xe0) == 0xc0)              /* clear */
	{
	        if(ck_tx_seq_state())
	        {
	                reset_mac_timer();
	                u.s.mac_tx_seq_state++;
	                u.s.mac_tx_seq_state &= 1;
	                u.s.mac_state=MAC_IDLE;
	                process_bridge_layer(MAC,MAC_TX_COMPLETE,0);
	                return;
	        }
	        else
	        {
	                reset_mac_timer();
	                u.s.mac_state=MAC_IDLE;
	                process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
	                return;
	        }
	}
	if((u.s.mac_control & 0xe0)== 0x60)      /* rfp */
	{
	        reset_mac_timer();
	        u.s.mac_state=MAC_IDLE;
	        process_bridge_layer(MAC,MAC_TX_COMPLETE,0);
	        process_mac_idle(size);
	        return;
	}
	reset_mac_timer();
	u.s.mac_state=MAC_IDLE;
	process_bridge_layer(MAC,MAC_TX_EOD_FAILURE,0);
}
/*************************************************************** */
static void process_tx_send_record()
{
	int                 control;
	int                 size;
	unsigned char       data_rem;

	data_rem=0;
	if((u.s.mac_tx_size - u.s.mac_tx_ptr) > 100)
	{
	        u.s.mac_tx_state=TX_S_DATA;
	        size=100;
	        control=0x20;                        /* data */
	        data_rem=(unsigned char)(((u.s.mac_tx_size - u.s.mac_tx_ptr) - 1
	}
	else
	{
	        u.s.mac_tx_state=TX_S_EOD;
	        size=(int)(u.s.mac_tx_size - u.s.mac_tx_ptr);
	        control=0x00;                        /* eod */
	}
	if(u.s.mac_tx_seq_state)
	        control |= 0x10;
```

```
        control |= u.s.l    ddress;
        send_ss_data(cont  l,(unsigned char)size,&br   e_tx_buffer[u.s.mac_tx_pt
        set_mac_timer(POLL_TIMEOUT);
        set_ignore_c188_timer(C188_DELAY_TIME);
}
/* ************************************************************** */
static void process_mac_rx_timeout()
{
        u.s.mac_retry_cnt++;
        if(u.s.mac_retry_cnt >= MAX_RX_TRIES)
        {
                reset_mac_timer();
                u.s.mac_state=MAC_IDLE;
                u.s.mac_rx_seq_state=SEQ_ACCEPT_ANY;
                check_tx_pending();
                return;
        }
        if(!(mac_acquire_channel()))
        {
                set_mac_backoff_time(0,T_4_MILLI);
                return;
        }
        switch(u.s.mac_rx_seq_state)
        {
                case SEQ_ACCEPT_ANY:
                case SEQ_ACCEPT_0:
                                mac_send_poll(0);
                                break;
                default:
                                mac_send_poll(1);
                                break;
        }
        set_mac_timer(RX_TIMEOUT);
}
/* ************************************************************** */
static void process_mac_rx_machine(size)
        int     size;
{
        char            frame_accept_sw;
        int             i;
        unsigned char   *pt1;
        unsigned char   *pt2;

        switch(u.s.mac_control & 0xe0)
        {
                case    0:                      /* eod */
                case    0x20:                   /* data */
                                switch(u.s.mac_rx_seq_state)
                                {
                                        case SEQ_ACCEPT_0:
                                                if(u.s.mac_control & 0x10)
                                                {
                                                        frame_accept_sw=0;
                                                        u.s.mac_rx_seq_state=SE
                                                }
                                                else
                                                {
                                                        frame_accept_sw=1;
                                                        u.s.mac_rx_seq_state=SE
                                                }
```

```
                        brea
                case SEQ_ACCE. _1:
                        if(u.s.mac_control & 0x10)
                        {
                                frame_accept_sw=1;
                                u.s.mac_rx_seq_state=SEQ
                        }
                        else
                        {
                                frame_accept_sw=0;
                                u.s.mac_rx_seq_state=SEQ
                        }
                        break;
                default:
                        u.s.mac_state=MAC_IDLE;
                        reset_mac_timer();
                        check_tx_pending();
                        return;
        }
        if(frame_accept_sw)
        {
                if((u.s.mac_rx_ptr + (unsigned int)size)
                {
                        u.s.mac_state=MAC_IDLE;
                        reset_mac_timer();
                        check_tx_pending();
                        return;
                }
                u.s.mac_retry_cnt=0;
                pt1=mac_rx_buffer;
                pt2=&bridge_rx_buffer[u.s.mac_rx_ptr];
                u.s.mac_rx_ptr += (unsigned int)size;
                for(i=0;i<size;i++)*pt2++=*pt1++;
        }
        if(u.s.mac_control & 0x20)      /* data */
        {
                if(u.s.mac_rx_seq_state==SEQ_ACCEPT_0)
                        mac_send_poll(0);
                else
                        mac_send_poll(1);
                set_mac_timer(RX_TIMEOUT);
                return;
        }
        if(u.s.mac_rx_seq_state==SEQ_ACCEPT_0)
                mac_send_clear(0);
        else
                mac_send_clear(1);
        u.s.mac_state=MAC_IDLE;
        reset_mac_timer();
        process_bridge_layer(MAC,MAC_RECORD,u.s.mac_rx_p
        check_tx_pending();
        return;
case    0x60:                   /* rfp */
        mac_send_poll(0);
        u.s.mac_rx_seq_state=SEQ_ACCEPT_0;
        set_mac_timer(RX_TIMEOUT);
        u.s.mac_rx_ptr=0;
        return;
default:
        break;
```

```
        }
        if(u.s.mac_rx_seq_state==SEQ_ACCEPT_1)
        {
                mac_send_reject(1);
        }
        else
        {
                mac_send_reject(0);
        }
        u.s.mac_state=MAC_IDLE;
        reset_mac_timer();
        check_tx_pending();
}
/* *************************************************************** */
static void process_mac_idle(size)
        int     size;
{
        unsigned char   *pt1;
        unsigned char   *pt2;
        int             i;

        if((u.s.mac_control & 0xe0) == 0)                       /* eod */
        {
                if(u.s.mac_dest_adr & 0x8000)
                {
                        pt1=mac_rx_buffer;
                        pt2=bridge_rx_buffer;
                        for(i=0;i<size;i++)*pt2++=*pt1++;
                        process_bridge_layer(MAC,MAC_RECORD,(unsigned int)size);
                        check_tx_pending();
                        return;
                }
        }
        if(u.s.mac_dest_adr & 0x8000)
        {
                check_tx_pending();
                return;
        }
        if((u.s.mac_control & 0xe0) == 0x60)    /* rfp  */
        {
                mac_send_poll(0);
                u.s.mac_rx_seq_state=SEQ_ACCEPT_0;
                u.s.mac_state=MAC_RX_MACHINE;
                set_mac_timer(RX_TIMEOUT);
                u.s.mac_retry_cnt=0;
                u.s.mac_rx_ptr=0;
                return;
        }
        if((u.s.mac_control & 0xe0) == 0x40)    /* enq */
        {
                if(u.s.mac_rx_seq_state==SEQ_ACCEPT_0)
                {
                        mac_send_clear(0);
                        check_tx_pending();
                        return;
                }
                if(u.s.mac_rx_seq_state==SEQ_ACCEPT_1)
                {
                        mac_send_clear(1);
                        check_tx_pending();
```

```
                        rn;
                }
        }
        check_tx_pending();
/* ************************************************************* */
static void mac_send_poll(seq)
        unsigned char   seq;
{
        unsigned char   data;

        if(seq)
        {
                data=0xf0;
        }
        else
        {
                data=0xe0;
        }
        data |= u.s.lan_address;
        send_ss_data(data,0,0,0,u.s.mac_data_rem);
        set_ignore_c188_timer(C188_DELAY_TIME);
}
/* ************************************************************* */
static void mac_send_rfp()
{
        unsigned char   data;

        u.s.mac_tx_seq_state=0;
        u.s.mac_tx_ptr=0;
        data=0x60;
        data |= u.s.lan_address;
        send_ss_data(data,0,0,0,(unsigned char)((u.s.mac_tx_size + 15)/16));
        set_ignore_c188_timer(C188_DELAY_TIME);
}
/* ************************************************************* */
static void mac_send_enq()
{
        unsigned char   data;

        if(u.s.mac_tx_seq_state)
        {
                data=0x50;
        }
        else
        {
                data=0x40;
        }
        data |= u.s.lan_address;
        send_ss_data(data,0,0,0,0);
        set_ignore_c188_timer(C188_DELAY_TIME);
}
/* ************************************************************* */
static void mac_send_reject(seq)
        unsigned char   seq;
{
        unsigned char   data;

        if(seq)
        {
```

```
                data=0xb
        }
        else
        {
                data=0xa0;
        }
        data |= u.s.lan_address;
        send_ss_data(data,0,0,0,0);

* ************************************************************* */
tatic void mac_send_clear(seq)
        unsigned char   seq;

        unsigned char   data;

        if(seq)
        {
                data=0xd0;
        }
        else
        {
                data=0xc0;
        }
        data |= u.s.lan_address;
        send_ss_data(data,0,0,0,0);

/* ************************************************************* */
static void send_ss_data(control,size,buffer,multicast,data_rem)
        unsigned char   control;
        unsigned char   size;
        unsigned char   *buffer;
        unsigned char   multicast;
        unsigned char   data_rem;
{
        unsigned int    j;
        unsigned char   prelude[6];

        j=u.s.base_address;
        if(multicast)j |= 0x8000;
        prelude[0]=(unsigned char)(j >> 8);
        prelude[1]=(unsigned char)j;
        j=u.s.short_address;
        if(multicast)j |= 0x8000;
        prelude[2]=(unsigned char)(j >> 8);
        prelude[3]=(unsigned char)j;
        prelude[4]=control;
        prelude[5]=data_rem;
        (*hdlc_write_data_ptr)(prelude,buffer,size);
}
/* ************************************************************** */
void ss_disable_rec()
{
        ss_write_control(3,0xc0);
}
/* ************************************************************** */
int ss_standby()
{
        if(p6dr & 0x08)return(0);
        return(1);
}
```

```
/* ******************************************************************** */
void ss_set_standby(type)
	int	type;
{
	unsigned char	i;

	if(type==TRUE)
	{
		p6 &=0xfd;
		p6dr=p6;		/* make sure rts low */
		for(i=0;i<40;i++)	/* delay */
		{
		}
		p6 &= 0xf7;
		p6dr=p6;
	}
	else
	{
		p6 |= 8;
		p6dr=p6;
		ss_write_control(9,0x80);
		ss_write_control(4,0x20);	/* hard wired in macro */
		ss_write_control(10,0x80);
		ss_write_control(7,0x7e);
		ss_write_control(3,0xc0);
		ss_write_control(5,0x60);
		ss_write_control(1,0x00);
		ss_write_control(11,0x28);
		ss_write_control(14,0x00);
		ss_write_control(15,0x00);
		ss_write_control(0,0x30);
		ss_write_control(3,0xd9);
	}
}
/* ******************************************************************** */
static void ss_write_control(adr,data)
	unsigned char	adr;
	unsigned char	data;
{
	hdlc_control_out=adr;
	hdlc_control_out=data;
}
/* ******************************************************************** */
static char ss_read_process()
{
	int		i;
	unsigned int	j;

	i=hdlc_data_in_buf[0];
	j=(unsigned int)i << 8;
	i=hdlc_data_in_buf[1];
	j |= (unsigned int)i;
	u.s.mac_dest_adr=j;
	i=hdlc_data_in_buf[2];
	j = (unsigned int)i << 8;
	i=hdlc_data_in_buf[3];
	u.s.mac_source_adr= (unsigned int)i | j;
	i=hdlc_data_in_buf[4];
	j = i & 7;
	if(j != u.s.lan_address)return(-1);
```

```
        u.s.mac_control=(unsigned char)i;
        i=hdlc_data_in_buf[5];
        u.s.mac_data_rem=(unsigned char)i;
        return(0);
}
/* ************************************************************** */
static void reset_mac_timer()
{
        unsigned char   t;

        mac_timer_flag=0;
        t=tftcsr;
        t &= 0xfb;
        tftcsr=t;
}
/* ************************************************************** */
static void set_mac_timer(time)
        unsigned int    time;
{
        unsigned char   t;

        mac_timer_flag=1;
        tftocr=0x10;
        tfocr_a_b=tffrc + time;
        t=tftcsr;
        t &= 0xfb;
        tftcsr=t;
}
/* ************************************************************** */
static void set_mac_backoff_time(unsigned int time, unsigned int rand_time)
{
        unsigned char   t;

        u.s.save_last_addr=0;
        mac_timer_flag=1;
        tftocr=0x10;
        tfocr_a_b = tffrc + ((tffrc ^ u.s.short_address)/rand_time)+time;
        t=tftcsr;
        t &= 0xfb;
        tftcsr=t;
}
/* ************************************************************** */
static int mac_acquire_channel()
{
        unsigned char   t;
        unsigned char   i;

        tftocr=0x10;                        /* select ocr b */
        tfocr_a_b = tffrc + T_6_MILLI;
        t=tftcsr;
        t &= 0xfb;
        tftcsr=t;
        for(;(tftcsr & 0x04)==0;)
        {
                for(i=0;i<30;i++)               /* check for falsing */
                {
                        if(p6dr & 0x01)break;
                }
                if(i >=30)return(0);
        }
```

```
        return(1);
}
/* ************************************************************ */
void process_mac_layer(type,size)
        unsigned char   type;
        int             size;
{
        if(type==DATA)
        {
                if(ss_read_process() < 0)return;
                if((u.s.mac_source_adr & 0x7fff) == u.s.save_base)
                {
                        if(mac_rx_strength >= (u.s.save_strength-2))
                        {
                                u.s.save_strength=mac_rx_strength;
                                u.s.save_base_timer=3000;
                        }
                }
                if((u.s.mac_source_adr & 0x7fff) == u.s.base_address)
                {
                        if(mac_rx_strength >= (u.s.strength-2))
                        {
                                u.s.strength=mac_rx_strength;
                        }
                }
                process_mac_layer_data_entry(size-6);
                return;
        }
        if(type==TIMER)
        {
                process_mac_layer_timeout();
                return;
        }
        if(type==BRIDGE_LOW)
        {
                process_mac_bridge_interface(size);
                return;
        }
        return;
}
/* ************************************************************ */
```

```
* **********************  ************************
*                 bridge process                          */
* ******************************************************* */
define EXTERN                         extern
include                               "ssh8.h"
define DS2400_DATA                    0x04
define P5_CONFIG                      0xfd
define P5_CONFIG_DS_IN                (P5_CONFIG & (~DS2400_DATA))
define SCL                            0x40
define SDA                            0x20
define CODLD                          0x04
define CODDAT                         0x02
define CODCLK                         0x01
define RETURN_NO                      0
define RETURN_YES                     1
tatic void process_bridge_from_mac();
tatic unsigned char get_bridge_high_tx_buffer();
tatic void write_bridge_high_tx_buffer();
tatic void send_bridge_high_tx_buffer();
xtern int ss_standby();
xtern void ss_set_standby();
static void process_bridge_high();
static unsigned char process_low_bridge_hello();
void memcpy();
static void set_hello_timer();
static unsigned char check_on_charger();
static void process_rd_long_id();
static void process_rd_version();
static void process_rd_diag();
void process_mac_layer();
static void ds2400_reset();
static void ds2400_write();
static unsigned char ds2400_read();
static void do_crc();
static void int_c188();
static void int_high_speed();
static int get_high_speed();
static void put_high_speed();
static void init_code();
static void load_code();
static void prog_code();
static void high_speed_delay();
void process_bridge_layer();
int c188_read_process();
static void i2badr(unsigned char);
static void i2bend();
static void i2bwrt(unsigned char);
static unsigned char i2brd();
static void delay_5us();
static void sda_high();
static void sda_low();
static void scl_high();
static void scl_low();
static void sda_output_mode();
static void sda_input_mode();
static void wrt_eeprom(unsigned char,unsigned char);
static unsigned char rd_eeprom(unsigned char);
static unsigned char rd_agc(void);
static unsigned char rd_tx_power(void);
static void bh_code_load(int);
```

```
static void bh_self_test_   nt);
static void bh_self_test_2(int);
static void bh_self_test_3(int);
static void bh_test_code_load(void);
void memset(void *to, unsigned char, unsigned int size);
extern void write_h8_com();
extern void set_ignore_c188_timer(unsigned char);
/* ************************************************************ */
extern unsigned char            mac_enable_sw;
extern void                     (*process_mac_ptr)();
extern void                     (*process_bridge_ptr)();
extern int                      (*c188_read_process_ptr)();
extern void                     (*ss_transmitter_setup_ptr)();
extern void                     (*ss_write_ptr)();
extern unsigned int             (*write_c188_response_ptr)();
extern unsigned char            power_control_sw;
extern unsigned char            mac_rx_strength;
/* ************************************************************ */
static unsigned char            crc;
/* ************************************************************ */
const unsigned char             code_tab_type_2[]=
{
        0x02,0x76,0x8d,0x37,0x36,0xb8,0x67,0xd2,0x4b,0xe6,0x1d,0x6c,0xec,0xb1,0x
        0xa5,0x63,0x68,0x28,0xbb,0x23,0xdb,0xa6,0x65,0xdb,0xc4,0xdd,0x14,0x16,0x
        0xa1,0x25,0x71,0x38,0x80,0xc1,0x8d,0x5d,0xba,0xb1,0x83,0x01,0x1c,0x8e,0x
        0x5d,0x82,0x86,0xc6,0xdb,0x36,0x46,0x78,0x1e,0x62,0x6c,0xdb,0x63,0x61,0x
        0xde,0xdf,0xf8,0x39,0xb3,0xb8,0xd3,0x5f,0xfa,0xcb,0x1d,0xcd,0x9c,0x1f,0x
        0xc3,0xa1,0x29,0x1c,0xa6,0x9f,0x50,0x2c,0x34,0x0a,0xf9,0x65,0x38,0x94,0x
        0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0x
        0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x
        0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0x
        0x02,0x76,0x8d,0x37,0x36,0xb8,0x67,0xd2,0x4b,0xe6,0x1d,0x6c,0xec,0xb1,0x
};
const unsigned char             code_tab_type_1[]=
{
        0x02,0x76,0x8d,0x37,0x36,0xb8,0x67,0xd3,0x4b,0xe6,0x1d,0x6c,0xec,0xb1,0x
        0xa5,0x63,0x68,0x28,0xbb,0x23,0xdb,0xa6,0x65,0xdb,0xc4,0xdd,0x14,0x16,0x
        0xa1,0x25,0x71,0x38,0x80,0xc1,0x8d,0x5d,0xba,0xb1,0x83,0x01,0x1c,0x8e,0x
        0x5d,0x82,0x86,0xc6,0xdb,0x36,0x46,0x78,0x1e,0x62,0x6c,0xdb,0x63,0x61,0x
        0xde,0xdf,0xf8,0x39,0xb3,0xb8,0xd3,0x5f,0xfa,0xcb,0x1d,0xcd,0x9c,0x1f,0
        0xc3,0xa1,0x29,0x1c,0xa6,0x9f,0x50,0x2c,0x34,0x0a,0xf9,0x65,0x38,0x94,0x
        0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0x
        0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x
        0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0xaa,0x
        0x02,0x76,0x8d,0x37,0x36,0xb8,0x67,0xd2,0x4b,0xe6,0x1d,0x6c,0xec,0xb1,0x
};
/* ************************************************************ */
void memcpy(void *to, void *from, unsigned int size)
{
        if(!size)return;
        asm(void,"              mov.w   @(4,r6),r5      ;r5=to");
        asm(void,"              mov.w   @(6,r6),r4      ;r4=from");
        asm(void,"              mov.w   @(8,r6),r1      ;r1=size");
        asm(void,"              push    r2                      ");
        asm(void,"              sub.w   r2,r2                   ");
        asm(void,"              adds    #1,r2                   ");

        asm(void,"memcpy1:");
        asm(void,"              mov.b   @r4+,r0l");
        asm(void,"              mov.b   r0l,@r5");
```

```
        asm(void,"              adds    #1,r5   ");
        asm(void,"              sub.w   r2,r1   ");
        asm(void,"              bne     memcpy1 ");
        asm(void,"              pop     r2      ");
}
/* ************************************************************** */
void memset(void *to, unsigned char data, unsigned int size)
{
        if(!size)return;
        asm(void,"              mov.w   @(4,r6),r5      ;r5=to");
        asm(void,"              mov.w   @(6,r6),r4      ;r4=data");
        asm(void,"              mov.w   @(8,r6),r1      ;r1=size");
        asm(void,"              push    r2                      ");
        asm(void,"              sub.w   r2,r2                   ");
        asm(void,"              adds    #1,r2                   ");
        asm(void,"memset1:");
        asm(void,"              mov.b   r4l,@r5");
        asm(void,"              adds    #1,r5   ");
        asm(void,"              sub.w   r2,r1   ");
        asm(void,"              bne     memset1 ");
        asm(void,"              pop     r2              ");
}
/* ************************************************************** */
void bridge_init()
{
        unsigned char   i;

        disable;
        sda_output_mode();
        scl_low();
        sda_high();
        scl_high();
        memset(&u,0,sizeof(u));
        p8ddr=0xf2;
        p8 |= 1;
        p8dr=p8;
        u.s.board_type=2;
        if(p8dr & 1)
        {
                u.s.board_type=1;
        }
        u.s.interrupt_cnt=3;
        u.s.base_address=0xffff;
        iscr=0x77;
        ier=C188_INT_ENABLE+BRIDGE_LOW_INT_ENABLE;
        tftcr=TFTCR_INIT;                               /* clock divided by 8 */
        for(i=0;i<48;i++)diag_cnt[i]=0;
        power_control_sw=TRUE;
        process_mac_ptr=process_mac_layer;
        process_bridge_ptr=process_bridge_layer;
        c188_read_process_ptr=c188_read_process;
        ss_set_standby(TRUE);
        enable;
}
/* ************************************************************** */
void process_bridge_layer(process,type,size)
        unsigned char   process;
        unsigned char   type;
        unsigned int    size;
{
```

```
switch(process)
{
        case MAC:
                        process_bridge_from_mac(type,size);
                        return;
        case TIMER_LOW:
                        if(u.s.save_base_timer)u.s.save_base_timer--;
                        if(u.s.save_base_timer==0)
                        {
                                if( u.s.save_base != 0)
                                {
                                        if(u.s.base_info_event==0)
                                        {
                                                u.s.save_base=0;
                                                u.s.base_info_event=1;
                                        }
                                }
                        }
                        if(u.s.interrupt_cnt)u.s.interrupt_cnt--;
                        if(!(u.s.interrupt_cnt))
                        {
                                if((u.s.bridge_high_tx_special_len) ||
                                  (u.s.bridge_tx_notify_event) ||
                                  (u.s.bridge_timer_event) ||
                                  (u.s.bridge_hello_event) ||
                                  (u.s.bridge_high_tx_buffer_cnt) ||
                                  (u.s.base_info_event))
                                {
                                        int_c188();
                                }
                                u.s.interrupt_cnt=3;
                        }
                        if(u.s.bridge_hello_watch_enable)
                        {
                                if(u.s.hello_on_timer_cnt)u.s.hello_on_t
                                if(u.s.hello_on_timer_cnt==0)
                                {
                                        mac_enable_sw=TRUE;
                                        u.s.missing_hello_cnt++;
                                        u.s.old_seed=((u.s.old_seed + 3
                                        set_hello_timer(u.s.old_seed,0)
                                        u.s.hello_off_timer_cnt=HELLO_WA
                                        if(ss_standby())
                                                ss_set_standby(FALSE);
                                        if(u.s.missing_hello_cnt > MAX_H
                                        {
                                                u.s.missing_hello_cnt=0;
                                                u.s.bridge_hello_event=1
                                                int_c188();
                                        }
                                }
                                if(u.s.hello_off_timer_cnt)u.s.hello_off
                                if(u.s.non_hello_off_timer_cnt)
                                {
                                        u.s.non_hello_off_timer_cnt--;
                                }
                                else
                                {
                                        if((u.s.tx_pending_sw) || (u.s.
                                                u.s.non_hello_off_timer_
```

```
                                        }
                                        if((u.s.hello_off_timer_cnt==0) &&
                                           (u.s.non_hello_off_timer_cnt==0))
                                        {
                                                ss_set_standby(TRUE);
                                                mac_enable_sw=FALSE;
                                        }
                                }
                                return;
                case TIMER_HIGH:
                                disable;
                                ier &=~BRIDGE_HIGH_INT_ENABLE;
                                enable;
                                if(u.s.bh_timer_in_use_sw)
                                {
                                        u.s.bh_timer_in_use_sw=0;
                                        u.s.bridge_timer_event=1;
                                        u.s.bridge_timer_opt=u.s.bh_timer_versi
                                        int_c188();
                                }
                                return;
                case BRIDGE_HIGH:
                                process_bridge_high(size);
                                return;
                case BRIDGE_POWER_CONTROL:
                                if(u.s.c188_sent_sw)
                                {
                                        u.s.c188_sent_sw=0;
                                        tftocr=0;                       /* select ocr a
                                        tfocr_a_b=tffrc + T_250_MICRO;
                                        tftcsr &= 0xf7;
                                        for(;!(tftcsr & 0x08);)
                                        {
                                                if((c188_sw) || (bridge_low_time
                                                {
                                                        return;
                                                }
                                        }
                                }
                                disable;
                                if((c188_sw) || (bridge_low_timer_sw) || (bridge
                                {
                                        enable;
                                        return;
                                }
                                enable;
                                sleep;
                                tftcr=TFTCR_INIT;
                                return;
                default:
                                break;
        }
}
/* ************************************************************** */
static void process_bridge_from_mac(type,size)
        unsigned char   type;
        unsigned int    size;
{
        unsigned int    j;
```

```
	if(type >= 0x20)    rn;
	diag_cnt[type]++;
	if(type >= 0x10)                    /* rx machine */
	{
		if(type != MAC_RECORD)return;
		if(process_low_bridge_hello(size)==RETURN_NO)return;
		j=get_bridge_high_tx_buffer();
		if(!(j))
		{
			diag_cnt[BUF_NOT_AVAIL]++;
			return;
		}
		write_bridge_high_tx_buffer(BH_READ);
		write_bridge_high_tx_buffer((unsigned char)(u.s.mac_dest_adr >>
		write_bridge_high_tx_buffer((unsigned char)(u.s.mac_dest_adr & 0
		write_bridge_high_tx_buffer((unsigned char)(u.s.mac_source_adr >
		write_bridge_high_tx_buffer((unsigned char)(u.s.mac_source_adr &
		write_bridge_high_tx_buffer((unsigned char)(mac_rx_strength));
		memcpy(&bridge_high_tx_buffer[u.s.bridge_high_tx_buffer_lead][u.
		u.s.bridge_high_tx_buffer_ptr += size;

		                            /* holdoff c188 if possible 3270 large s
		send_bridge_high_tx_buffer();
		if((size > 1030) && (u.s.bridge_high_tx_buffer_cnt==1))
		{
			set_ignore_c188_timer(C188_LONG_DELAY_TIME);
		}
		return;
	}
	u.s.bridge_tx_notify_event=type | 0x80;
	int_c188();
}
/*************************************************************** */
static unsigned char process_low_bridge_hello(size)
	unsigned int    size;
{
	unsigned char   i;
	unsigned int    j;
	unsigned char   k;
	int             l;
	unsigned int    m;
	unsigned int    n;
	unsigned char   seed;
	unsigned char   offset;
	unsigned int    cost;


	if(u.s.bridge_hello_watch_enable==0)return(RETURN_YES);
	if((u.s.mac_dest_adr & 0x8000)==0)return(RETURN_YES);
	i=bridge_rx_buffer[0];
	if(size < 2)return(RETURN_NO);
	if(!(i & 0x10))return(RETURN_NO);            /* make sure it response
	if((i & 0x07) != 0x02)return(RETURN_YES);     /* not hello frame */
	switch(i & 0xc0)
	{
		case 0:
			j=6;
			break;
		case 0x40:
			j=2;
```

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```
                  k;
        default:
                return(RETURN_YES);
    }
                                        /* j pts to cost to root */
    cost=bridge_rx_buffer[j++];
    cost <<= 8;
    cost |=bridge_rx_buffer[j++];
    if(cost==0xffff)return(RETURN_YES);
                                        /* j pts to seed/attach */
    seed = bridge_rx_buffer[j];
    seed >>= 2;
    seed &= 0x3f;
    j++;
                                        /* j pts to offset */
    offset = bridge_rx_buffer[j];
    j++;
                                        /* j pts to priority */
    j++;
                                        /* j pts to root id seq number *
    if(u.s.root_id_seq_number < 0)
    {
            u.s.root_id_seq_number=bridge_rx_buffer[j];
    }
    else
    {
            if(u.s.root_id_seq_number != bridge_rx_buffer[j])
                    return(RETURN_YES);
    }
    j++;
                                        /* j pts to optional fields */
    for(;;)
    {
            i=bridge_rx_buffer[j];
            switch(i & 0x7f)
            {
                    case 0x04:              /* detached list */
                    case 0x05:              /* pending list */
                                    j++;
                                    k=bridge_rx_buffer[j];
                                    if(k & 1)return(RETURN_YES);
                                    j++;
                                    k >>= 1;
                                    n=(u.s.short_address & 0x07ff) | 0x0800;
                                    for(l=0;l<k;l++)
                                    {
                                            m=bridge_rx_buffer[j++];
                                            m <<= 8;
                                            m |= (bridge_rx_buffer[j++] & 0x
                                            if(m==n)return(RETURN_YES);
                                    }
                                    break;
                    case 0x0a:              /* root long id */
                    case 0x0b:              /* root alais */
                                    j++;
                                    k=bridge_rx_buffer[j];
                                    if(k != u.s.root_id_len)return(RETURN_YI
                                    j++;
                                    for(l=0;l<k;l++)
                                    {
```

```
                                        if(u   oot_id[1] != bridge_rx_b
                                }
                                break;
                default:
                                j++;
                                j +=bridge_rx_buffer[j];
                                j++;
                                break;
                }
                if(i & 0x80)break;
                if(j > size)break;
        }
        if((u.s.mac_source_adr & 0x7fff) != u.s.base_address)
        {
                if(cost > u.s.cost)return(RETURN_NO);
                if(mac_rx_strength <= u.s.strength)return(RETURN_NO);
                if((u.s.mac_source_adr & 0x7fff) != u.s.save_base)
                {
                        if(mac_rx_strength < u.s.save_strength)return(RETURN_NO)
                        u.s.save_cost=cost;
                        u.s.save_strength=mac_rx_strength;
                        u.s.save_base=u.s.mac_source_adr & 0x7fff;
                        u.s.save_base_timer=3000;
                        u.s.base_info_event=1;
                }
                return(RETURN_NO);
        }
        u.s.strength=mac_rx_strength;
        u.s.old_seed=seed;
        set_hello_timer(seed,offset);
        u.s.missing_hello_cnt=0;
        u.s.hello_off_timer_cnt=0;
        return(RETURN_NO);
}
/* ************************************************************ */
static unsigned char check_on_charger()
{
        if(p4dr & 0x10)return(0);
        return(1);
}
/* ************************************************************ */
/* compute next hello time                                      */
/* offset is in 10's of milliseconds                            */

static void set_hello_timer(seed,offset)
        unsigned char   seed;
        unsigned char   offset;
{
        unsigned int    next_slot;
        unsigned int    i;

        i=u.s.base_address;
        i += seed;
        next_slot=(i % HELLO_MOD_VAL) + HELLO_MOD_VAL;
        i=next_slot * HELLO_SLOT_SIZE;
        i -= offset;                    /* time in 10's of milliseconds */
        i >>=1;                         /* time in 20 milliseconds */
        if(i >150)i=100;                /* time should never be greater then 3 s
        u.s.hello_on_timer_cnt=i;
}
```